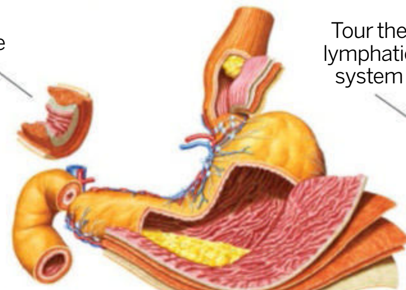
HUMAN ANATOMY | THE BODY AT WORK | CURIOUS QUESTIONS

NEW

What does the spinal cord do?



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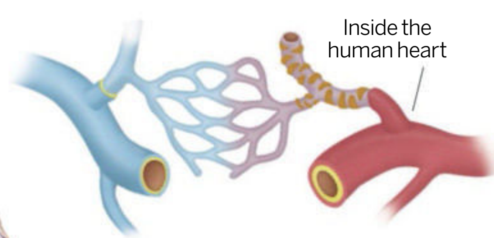

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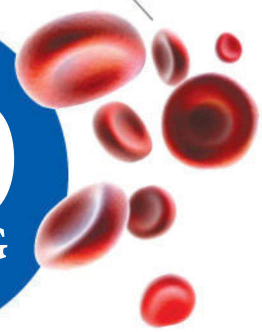

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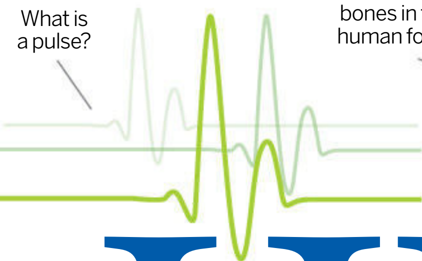
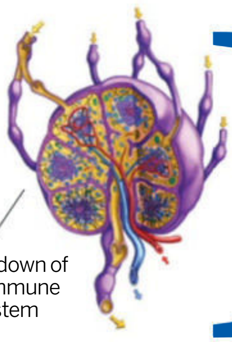


What is a pulse?

How many bones in the human foot?

HOW IT WORKS BOOK OF THE HUMAN BODY

OVER 500 AMAZING FACTS



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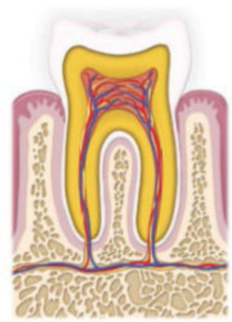

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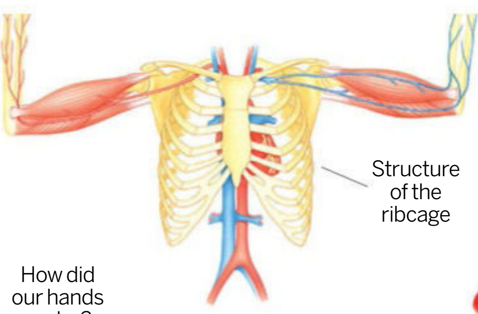
EVERYTHING YOU NEED TO KNOW ABOUT THE HUMAN BODY



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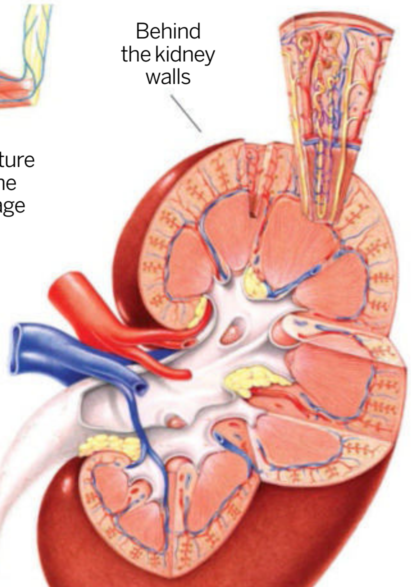

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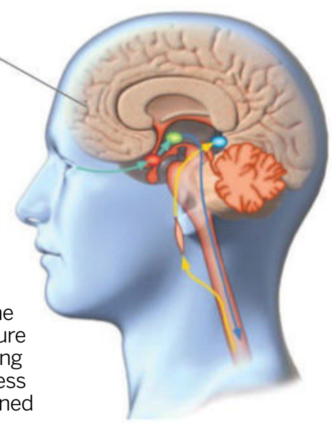

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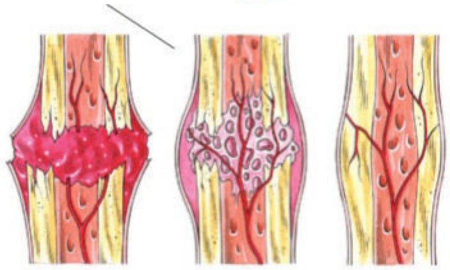

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PACKED FULL OF FASCINATING FACTS, IMAGES & ILLUSTRATIONS

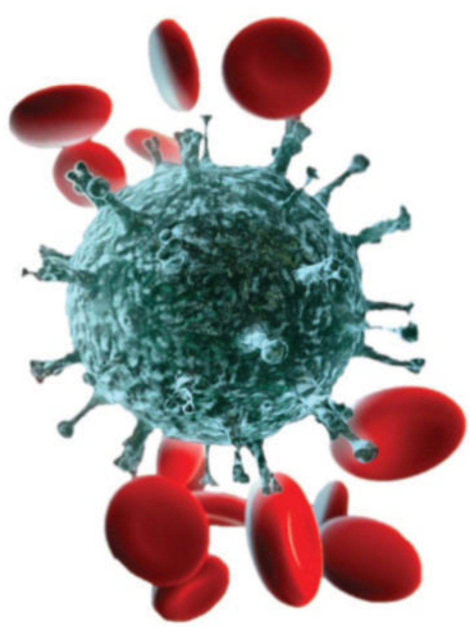
Welcome to

HOW IT WORKS

BOOK OF

THE HUMAN BODY

The human body is truly an amazing thing. Capable of awe-inspiring feats of speed and agility, while being mind-blowing in complexity, our bodies are unmatched by any other species on Earth. In this new edition of the Book of the Human Body, we explore our amazing anatomy in fine detail before delving into the intricacies of the complex processes, functions and systems that keep us going. For instance, did you know you really have 16 senses? We also explain the weirdest and most wonderful bodily phenomena, from blushing to hiccuping, cramps to blisters. We will tour the human body from head to toe, using anatomical illustrations, amazing photography and authoritative explanations to teach you more. This book will help you understand the wonder that is the human body and in no time you will begin to see yourself in a whole new light!



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Aaron Asadi

Head of Design
Ross Andrews

Production Editor
Jen Neal

Senior Art Editor
Greg Whitaker

Senior Designer
Sarah Bellman

Photographer
James Sheppard

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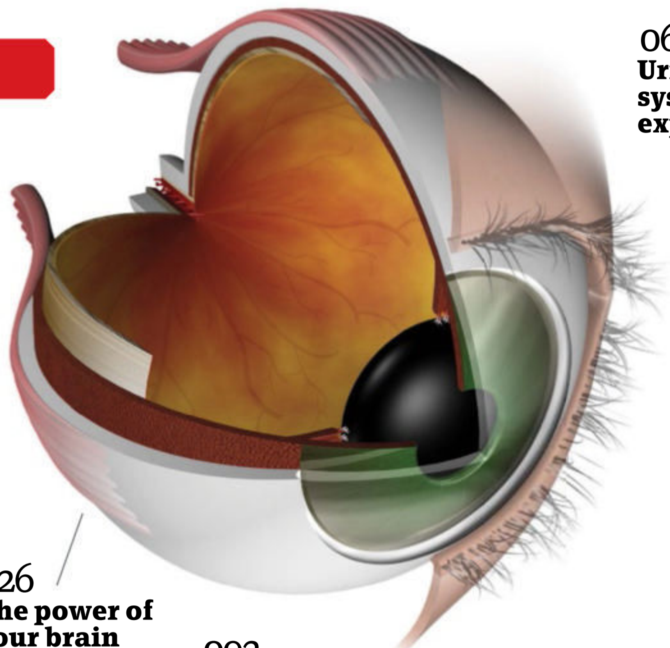

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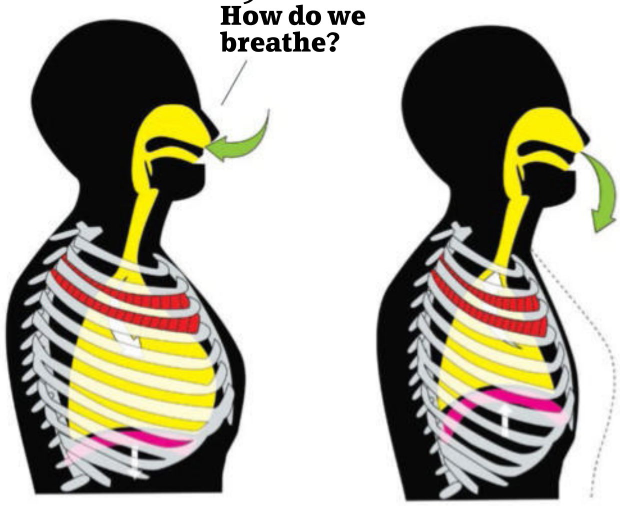

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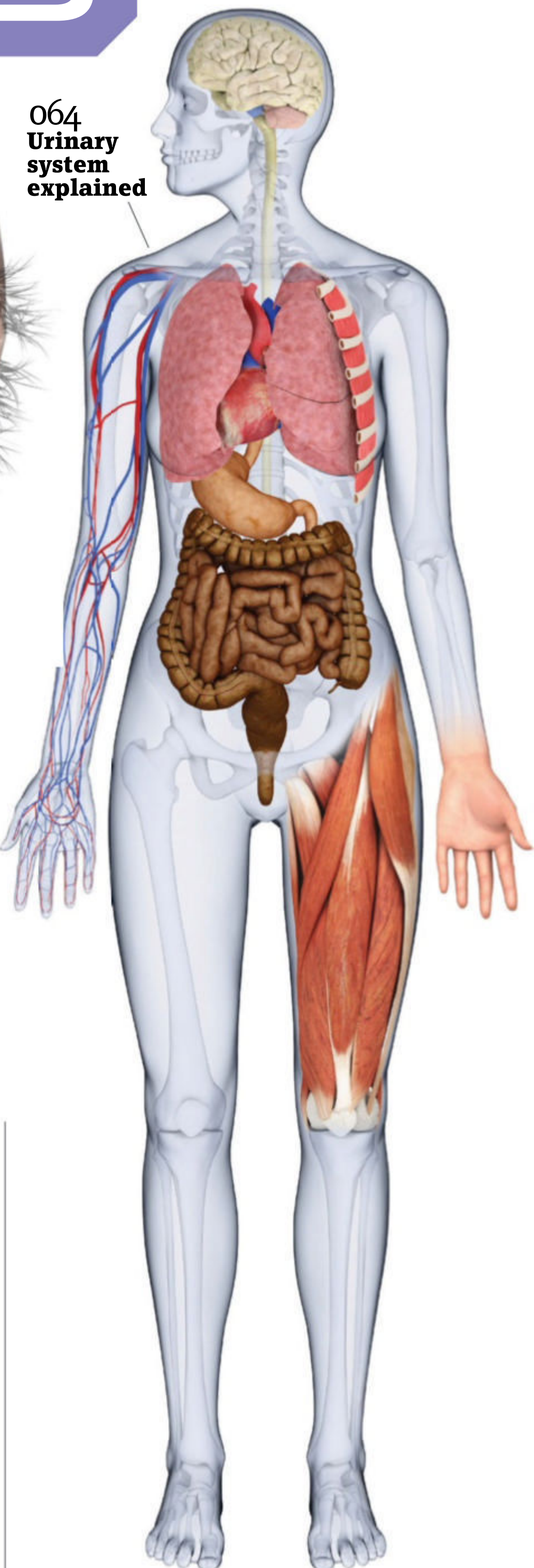

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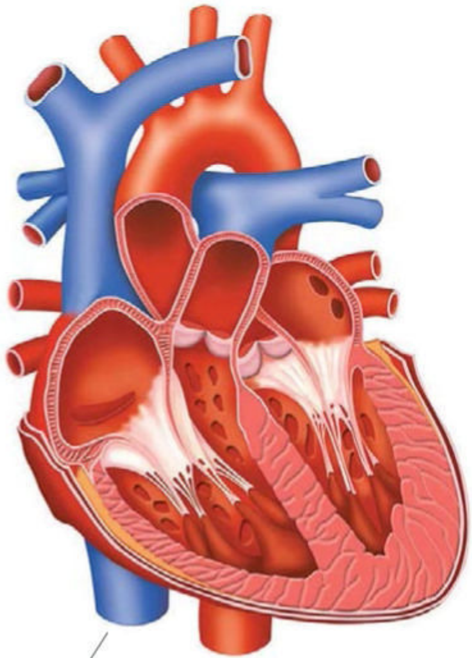

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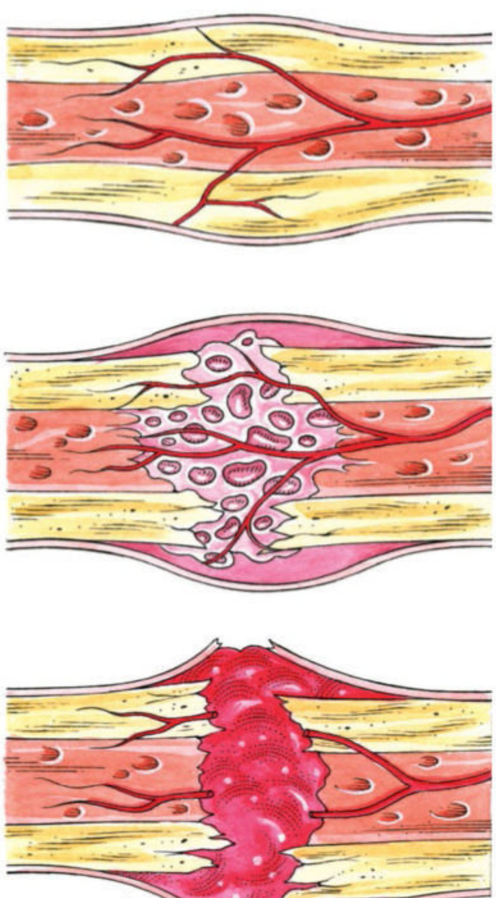

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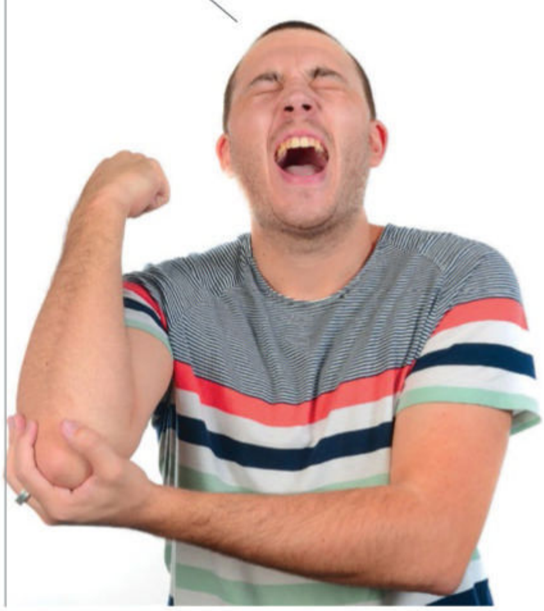

HUMAN ANATOMY

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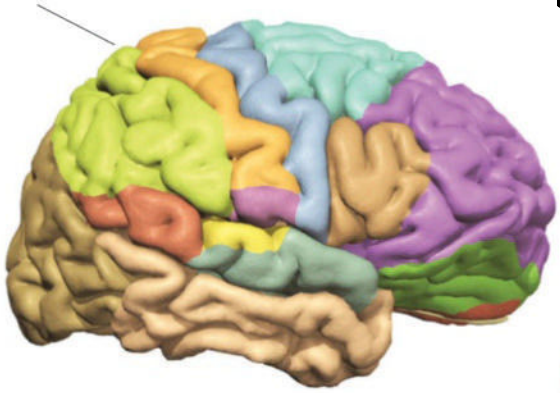

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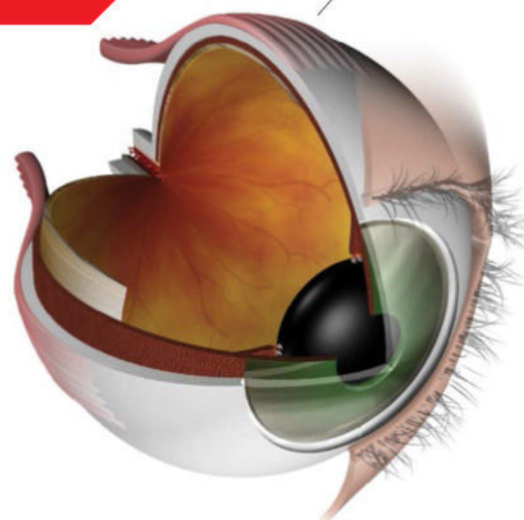

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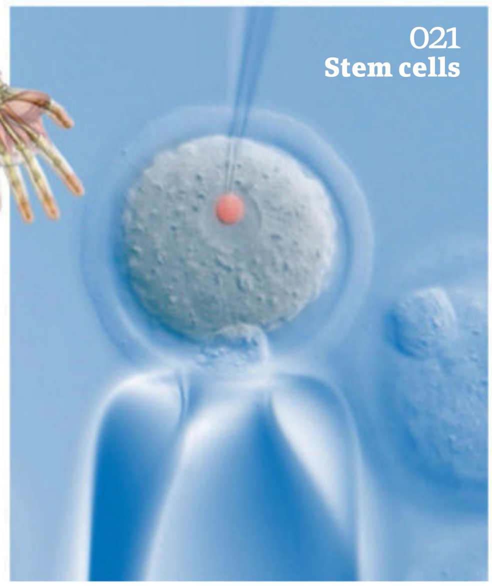

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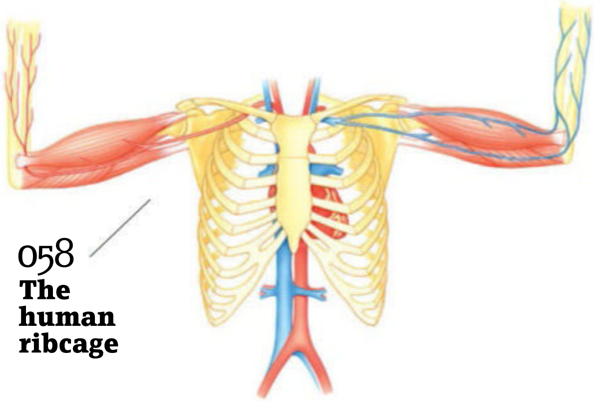
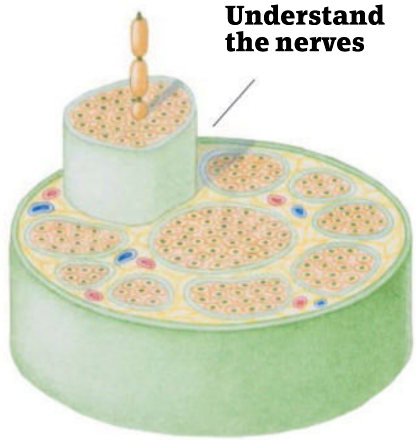
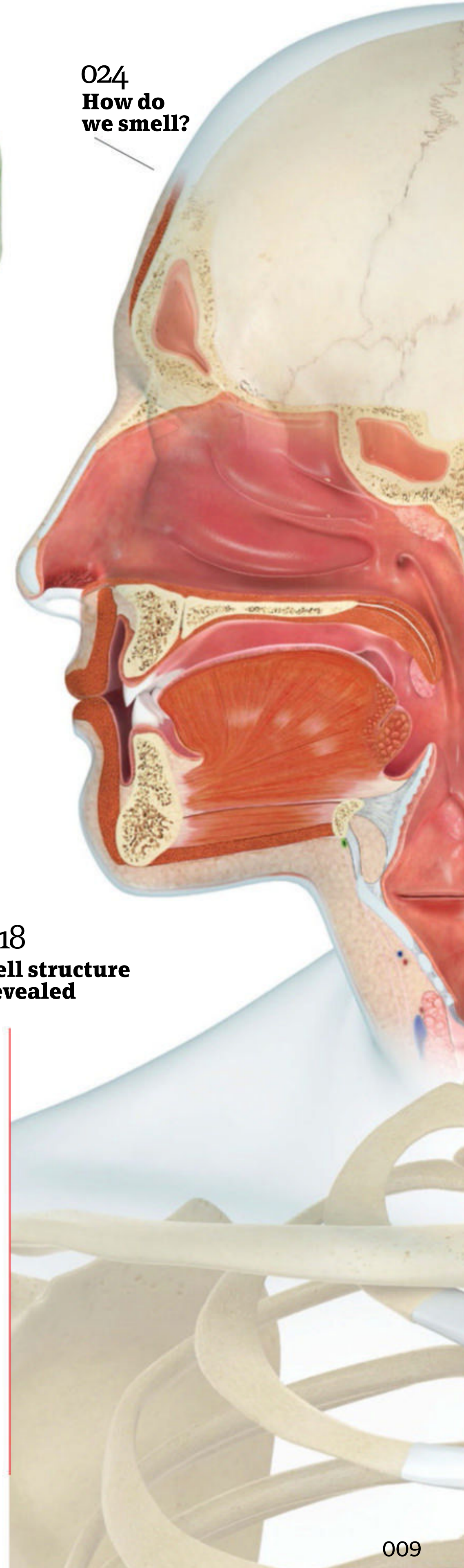
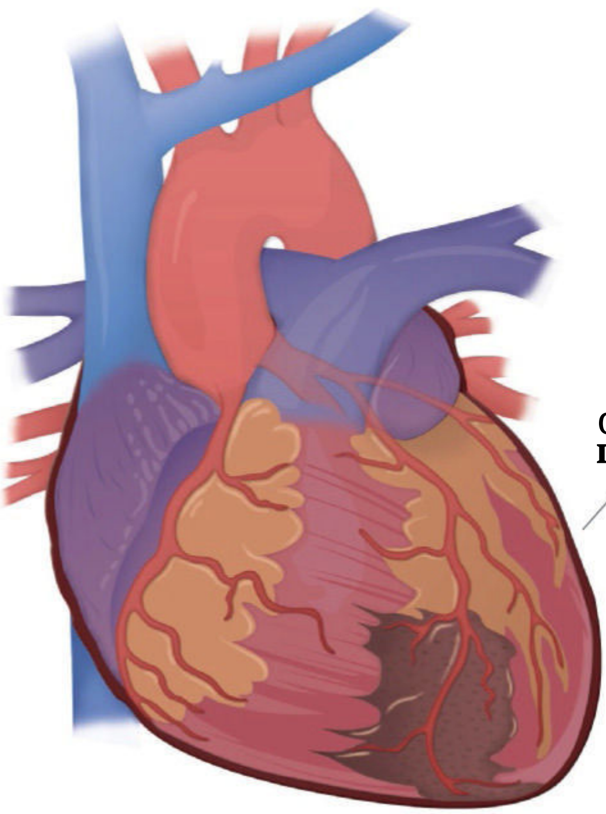






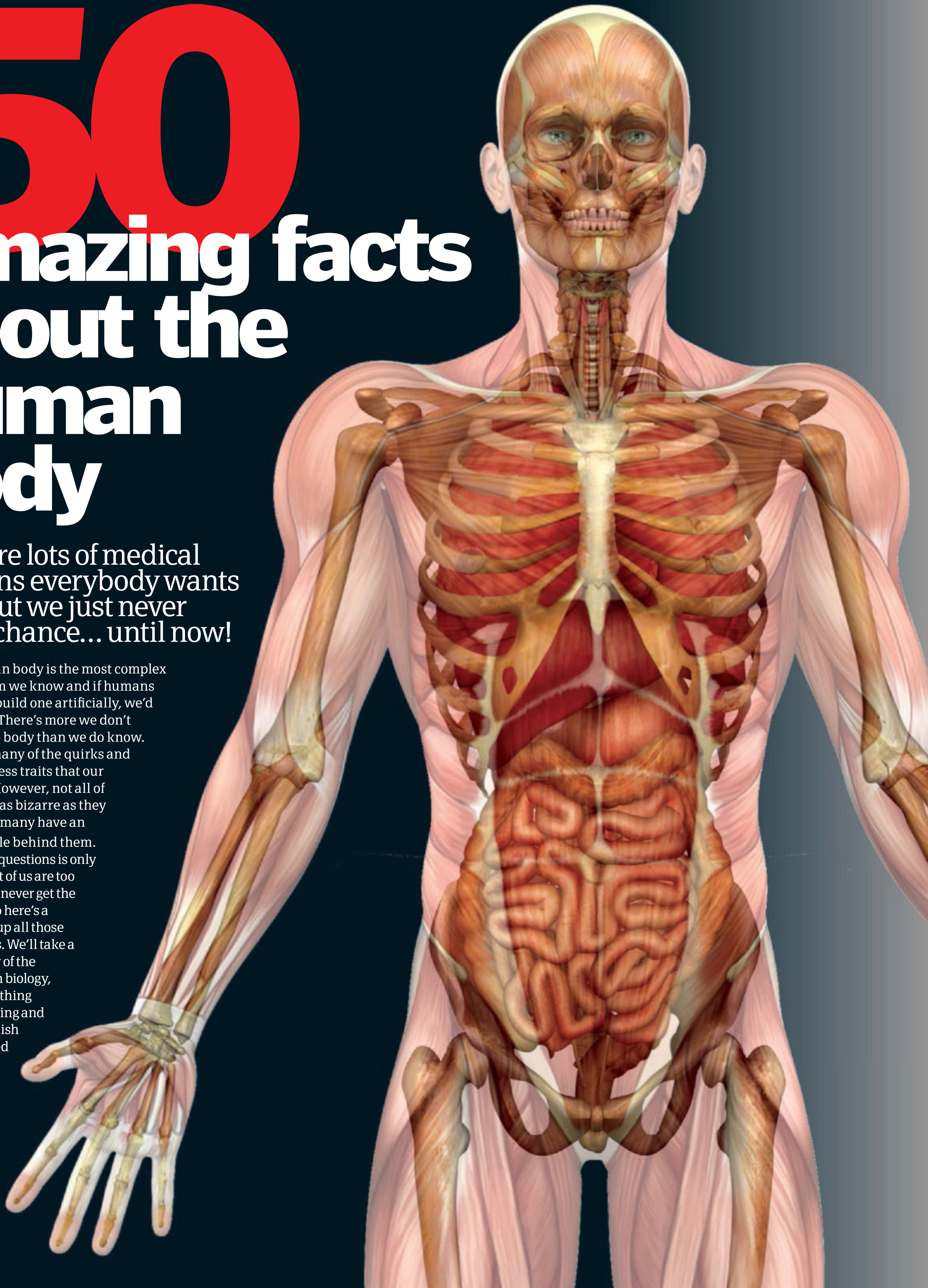


50 Amazing facts about the human body

There are lots of medical questions everybody wants to ask but we just never get the chance… until now!

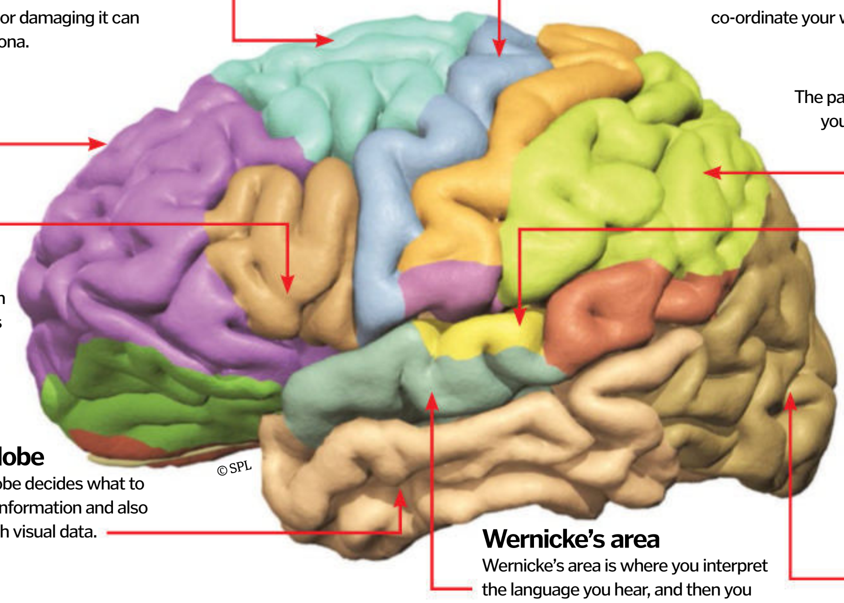
The human body is the most complex organism we know and if humans tried to build one artificially, we'd fail abysmally. There's more we don't know about the body than we do know. This includes many of the quirks and seemingly useless traits that our species carry. However, not all of these traits are as bizarre as they may seem, and many have an evolutionary tale behind them.

Asking these questions is only natural but most of us are too embarrassed or never get the opportunity – so here's a chance to clear up all those niggling queries. We'll take a head-to-toe tour of the quirks of human biology, looking at everything from tongue rolling and why we are ticklish through to pulled muscles and why we dream.



1 How do we think?

What are thoughts? This question will keep scientists, doctors and philosophers busy for decades to come. It all depends how you want to define the term 'thoughts'. Scientists may talk about synapse formation, pattern recognition and cerebral activation in response to a stimulus (such as seeing an apple and recognising it as such). Philosophers, and also many scientists, will argue that a network of neurons cannot possibly explain the many thousands of thoughts and emotions that we must deal with. A sports doctor might state that when you choose to run, you activate a series of well-trodden pathways that lead from your brain to your muscles in less than a second. There are some specifics we do know though – such as which areas of your brain are responsible for various types of thoughts and decisions.



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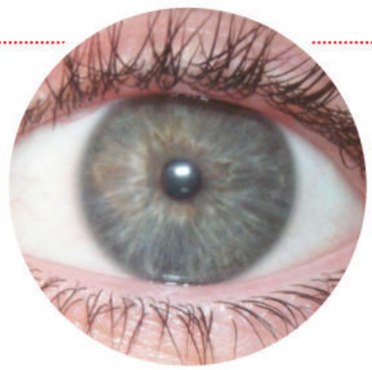
© Dora Pete

2 In the mornings, do we wake up or open our eyes first?

Sleep is a gift from nature, which is more complex than you think. There are five stages of sleep which represent the increasing depths of sleep – when you're suddenly wide awake and your eyes spring open, it's often a natural awakening and you're coming out of rapid eye movement (REM) sleep; you may well remember your dreams. If you're coming out of a different phase, eg when your alarm clock goes off, it will take longer and you might not want to open your eyes straight away!



3 Do eyeballs grow like the rest of the body?

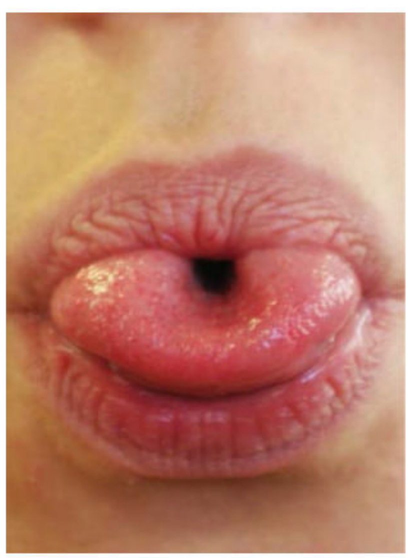
Only a small amount – hence why babies appear so beautiful, as their eyes are slightly out of proportion and so appear bigger.

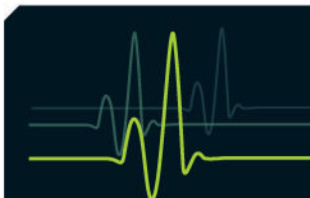
4 Why do we fiddle subconsciously? I'm constantly playing with my hair

This is a behavioural response – some people play with their hair when they're nervous or bored. For the vast majority of people such traits are perfectly normal. If they begin to interfere with your life, behavioural psychologists can help – but it's extremely rare that you'll end up there.

5 Why can some people roll their tongues but others can't?

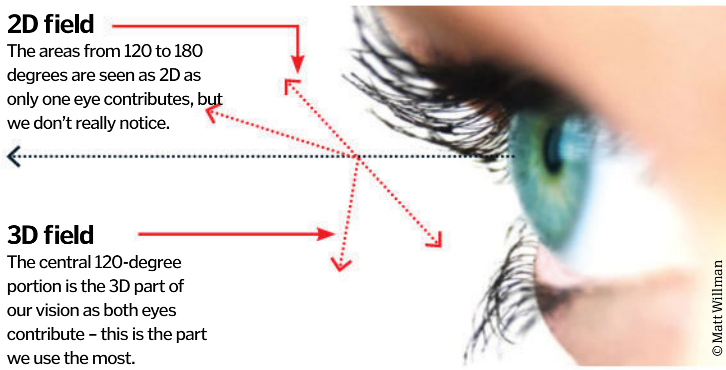
Although we're often taught in school that tongue rolling is due to genes, the truth is likely to be more complex. There is likely to be an overlap of genetic factors and environmental influence. Studies on families and twins have shown that it cannot be a case of simple genetic inheritance. Ask around – the fact that some people can learn to do it suggests that in at least some people it's environmental (ie a learned behaviour) rather than genetic (inborn).





6 What is a pulse?

When you feel your own pulse, you're feeling the direct transmission of your heartbeat down an artery. You can feel a pulse where you can compress an artery against a bone, eg the radial artery at the wrist. The carotid artery can be felt against the vertebral body, but beware: a) press too hard and you can faint, b) press both at the same time and you'll cut off the blood to your brain and, as a protective mechanism, you'll definitely faint!



© Matt Willman

7 What's my field of vision in degrees?

The human field of vision is just about 180 degrees. The central portion of this (approximately 120 degrees) is binocular or stereoscopic – ie both eyes contribute, allowing depth perception so that we can see in 3D. The peripheral edges are monocular, meaning that there is no overlap from the other eye so we see in 2D.

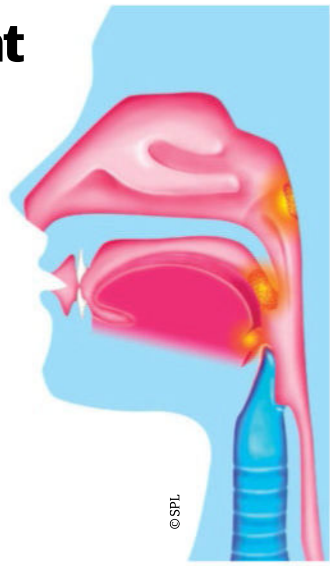
12 Why do we burp?

A burp is a natural release of gas from the stomach. This gas has either been swallowed or is the result of something you've ingested – such as a fizzy drink. The sound comes from the vibration of the oesophageal sphincter at the oesophago-gastric junction, which is the narrowest part of the gastrointestinal tract.

© Frettie

8 What is the point of tonsils?

The tonsils are collections of lymphatic tissues which are thought to help fight off pathogens from the upper respiratory tract. However, they themselves can sometimes become infected – leading to tonsillitis. The ones you can see at the back of your throat are just part of the ring of tonsils. You won't miss them if they're taken out for recurrent infections as the rest of your immune system will compensate.



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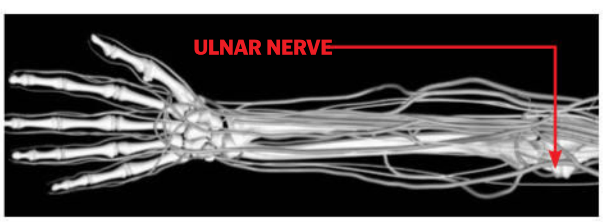
9 What are lips for?

Lips are predominantly used as a tactile sensory organ, typically for eating, but also for pleasure when kissing. They are also used to help fine-tune our voices when we speak.

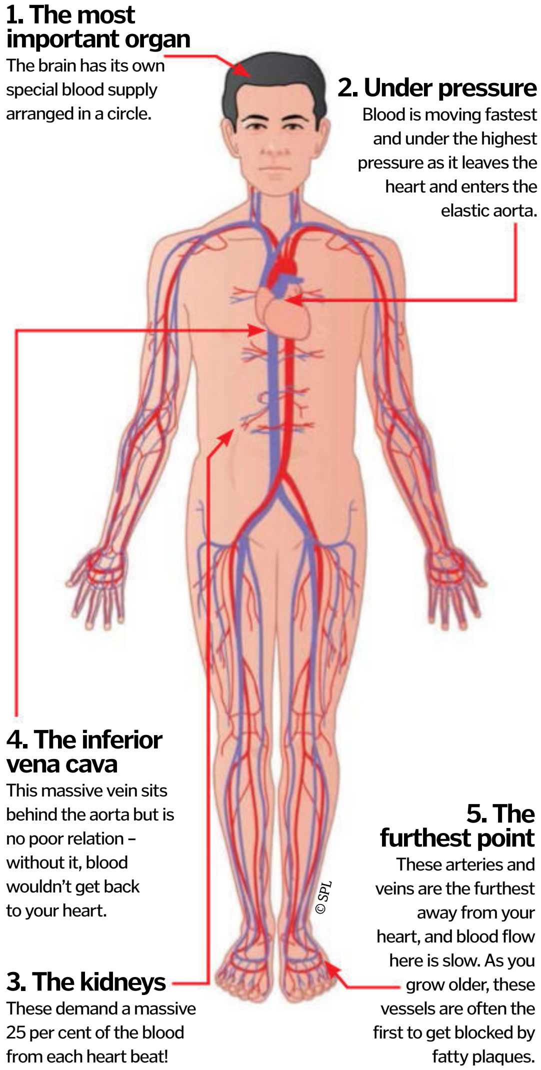
10 Why does it feel so weird when you hit your funny bone?

You're actually hitting the ulnar nerve as it wraps around the bony prominence of the 'humerus' bone, leading to a 'funny' sensation. Although not so funny as the brain interprets this sudden trauma as pain to your forearm and fingers!



11 How fast does blood travel round the human body?

Your total 'circulating volume' is about five litres. Each red blood cell within this has to go from your heart, down the motorway-like arteries, through the back-road capillary system, and then back through the rush-hour veins to get back to your heart. The process typically takes about a minute. When you're in a rush and your heart rate shoots up, the time reduces as the blood diverts from the less-important structures (eg large bowel) to the more essential (eg muscles).



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13 How many inches of hair does the average person grow from their head each year?

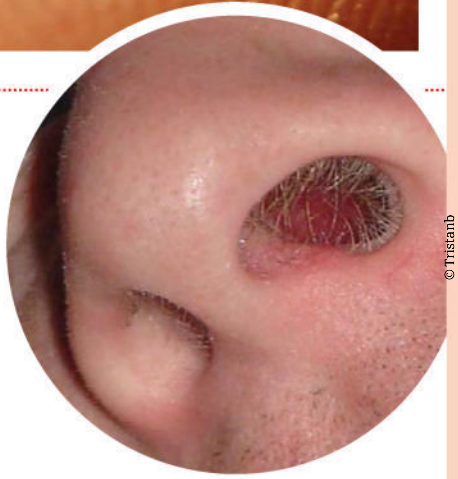
It's different for everybody – your age, nutrition, health status, genes and gender all play a role. In terms of length, anywhere between 0.5-1 inch (1.2-2.5cm) a month might be considered average, but don't be surprised if you're outside this range.

14 Why are everyone's fingerprints different?

Your fingerprints are fine ridges of skin in the tips of your fingers and toes. They are useful for improving the detection of small vibrations and to add friction for better grip. No two fingerprints are the same – either on your hands or between two people – and that's down to your unique set of genes.

15 Why do we only remember some dreams?

Dreams have fascinated humans for thousands of years. Some people think they are harmless while others think they are vital to our emotional wellbeing. Most people have four to eight dreams per night which are influenced by stress, anxiety and desires, but they remember very few of them. There is research to prove that if you awake from the rapid eye movement (REM) part of your sleep cycle, you're likely to remember your dreams more clearly.



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16 Why, as we get older, does hair growth become so erratic?

Hair follicles in different parts of your body are programmed by your genes to do different things, eg the follicles on your arm produce hair much slower than those on your head. Men can go bald due to a combination of genes and hormonal changes, which may not happen in other areas (eg nasal hair). It's different for everybody!

17 Why do we all have different coloured hair?

Most of it is down to the genes that result from when your parents come together to make you. Some hair colours win out (typically the dark ones) whereas some (eg blonde) are less strong in the genetic race.

18 Is it possible to keep your eyes open when you sneeze?

Your eyes remain shut as a defence mechanism to prevent the spray and nasal bacteria entering and infecting your eyes. The urban myth that your eyes will pop out if you keep them open is unlikely to happen – but keeping them shut will provide some protection against nasty bugs and viruses.

19 What gives me my personality?

Researchers have spent their whole lives trying to answer this one. Your personality forms in the front lobes of your brain, and there are clear personality types. Most of it is your environment – that is, your upbringing, education, surroundings. However some of it is genetic, although it's unclear how much. The strongest research in this comes from studying twins – what influences one set of twins to grow up and be best friends, yet in another pair, one might become a professor and the other a murderer.

20 WHY DO MEN HAVE NIPPLES?

Men and women are built from the same template, and these are just a remnant of a man's early development.

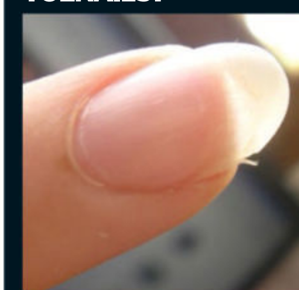
21 WHAT'S THE POINT OF EYEBROWS?

Biologically, eyebrows can help to keep sweat and rainwater from falling into your eyes. More importantly in humans, they are key aids to non-verbal communication.

22 WHAT IS A BELLY BUTTON?

The umbilicus is where a baby's blood flows through to get to the placenta to exchange oxygen and nutrients with the mother's blood. Once out, the umbilical cord is clamped several centimetres away from the baby and left to fall off. No one quite knows why you'll get an 'innie' or an 'outie' – it's probably all just luck.

23 WHY DO FINGERNAILS GROW FASTER THAN TOENAILS?



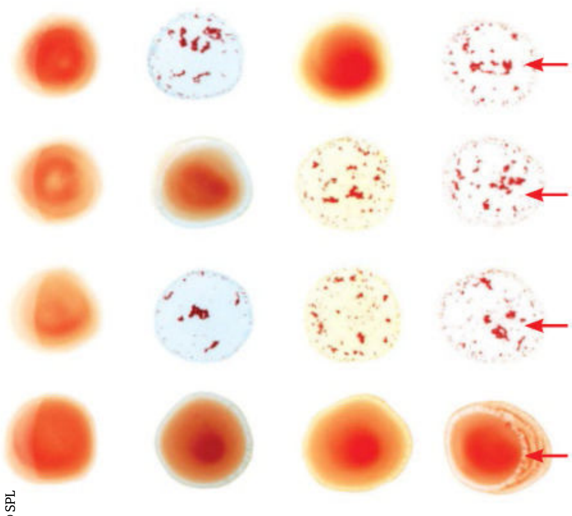
The longer the bone at the end of a digit, the faster the growth rate of the nail. However there are many other influences too – nutrition, sun exposure, activity, blood supply – and that's just to name a few.

24 WHY DOES MY ARM TINGLE AND FEEL HEAVY IF I FALL ASLEEP ON IT?

This happens because you're compressing a nerve as you're lying on your arm. There are several nerves supplying the skin of your arm and three supplying your hand (the radial, median and ulnar nerves), so depending on which part of your arm you lie on, you might tingle in your forearm, hand or fingers.

25 What makes some blood groups incompatible while others are universal?

Your blood type is determined by protein markers known as antigens on the surface of your red blood cells. You can have A antigens, B antigens, or none – in which case you're blood type O. However, if you don't have the antigen, your antibodies will attack foreign blood. If you're type A and you're given B, your antibodies attack the B antigens. However, if you're blood type AB, you can safely receive any type. Those who are blood group O have no antigens so can give blood to anyone, but they have antibodies to A and B so can only receive O back!



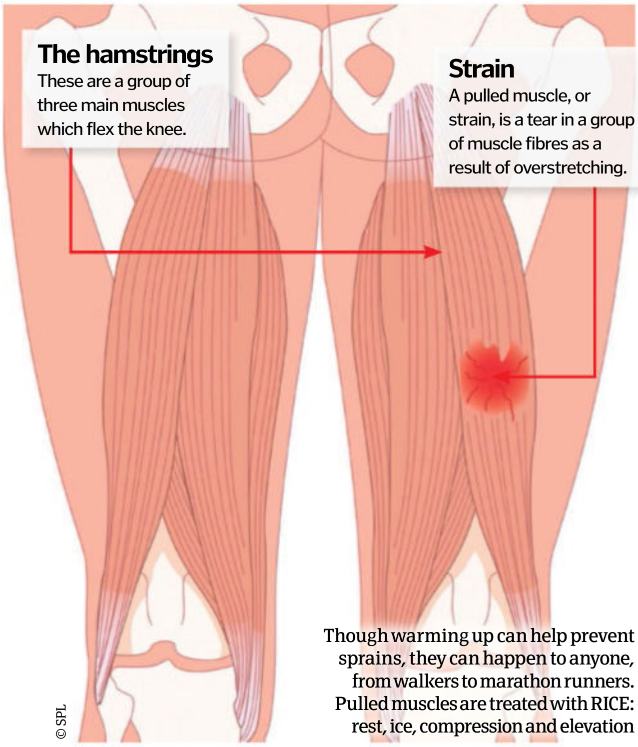
A
You have A antigens and B antibodies. You can receive blood groups A and O, but can't receive B. You can donate to A and AB.

B
You have B antigens and A antibodies. You can receive blood groups B and O, but can't receive A. You can donate to B and AB.

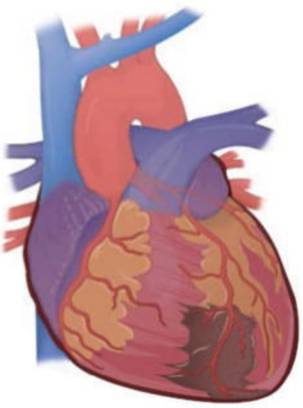
AB
You have A and B antigens and no antibodies. You can receive blood groups A, B, AB and O (universal recipient), and can donate to AB.

O
You have no antigens but have A and B antibodies. You can receive blood group O, but can't receive A, B or AB and can donate to all: A, B, AB and O.

26 What is a pulled muscle?



Though warming up can help prevent sprains, they can happen to anyone, from walkers to marathon runners. Pulled muscles are treated with RICE: rest, ice, compression and elevation



27 Which organ uses up the most oxygen?

The heart is the most efficient – it extracts 80 per cent of the oxygen from blood. But the liver gets the most blood – 40 per cent of the cardiac output compared to the kidneys, which get 25 per cent, and heart, which only receives 5 per cent.

28 What is the appendix? I've heard it has no use but can kill you…

The appendix is useful in cows for digesting grass and koala bears for digesting eucalyptus – koalas can have a 4m (13ft)-long appendix! In humans, however, the appendix has no useful function and is a remnant of our development. It typically measures 5-10cm (1.9-3.9in), but if it gets blocked it can get inflamed. If it isn't quickly removed, the appendix can burst and lead to widespread infection which can be lethal.

29 Why does people's skin turn yellow if they contract liver disease?

This yellow discolouration of the skin or the whites of the eyes is called jaundice. It's due to a buildup of bilirubin in your body, when normally this is excreted in the urine (hence why urine has a yellow tint). Diseases such as hepatitis and gallstones can lead to a buildup of bilirubin due to altered physiological processes, although there are many other causes.

30 What is the gag reflex?

31 Why are we ticklish?

Light touches, by feathers, spiders, insects or other humans, can stimulate fine nerve-endings in the skin which send impulses to the somatosensory cortex in the brain. Certain areas are more ticklish – such as the feet – which may indicate that it is a defence mechanism against unexpected predators. It is the unexpected nature of this stimulus that means you can be tickled. Although you can give yourself goosebumps through light tickling, you can't make yourself laugh.

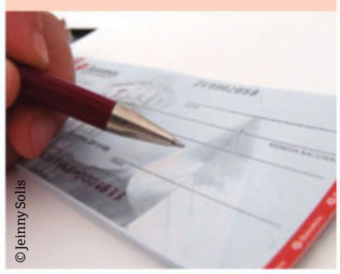
32 Why don't eyelashes keep growing?

Your eyelashes are formed from hair follicles, just like those on your head, arms and body. Each follicle is genetically programmed to function differently. Your eyelashes are programmed to grow to a certain length and even re-grow if they fall out, but they won't grow beyond a certain length, which is handy for seeing!

© shlomit g

33 What makes us left-handed?

One side of the brain is typically dominant over the other. Since each hemisphere of the brain controls the opposite side (ie the left controls the right side of your body), right-handed people have stronger left brain hemispheres. Occasionally you'll find an ambidextrous person, where hemispheres are co-dominant, and these people are equally capable with both right and left hands!



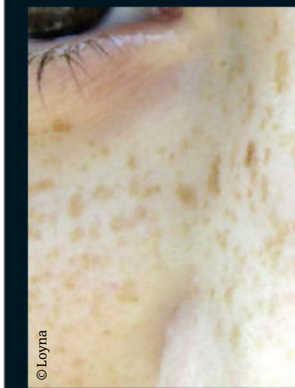
© Jeinny Solis

34 Could we survive on vitamins alone?

No, you need a diet balanced in carbohydrate, protein, fat, vitamins and minerals to survive. You can't cut one of these and expect to stay healthy. However, it's the proportions of these which keep us healthy and fit. You can get these from the five major food groups. Food charts can help with this balancing act.

35 Why do we get a high temperature when we're ill?

The immune response leads to inflammation and the release of inflammatory factors into your blood stream. These lead to an increased heart rate and blood flow, which increases your core body temperature – as if your body is doing exercise. This can lead to increased heat production and thus dehydration; for this reason, it's important to drink plenty of clear fluids when you're feeling unwell.



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36 WHY DO SOME PEOPLE HAVE FRECKLES?

Freckles are concentrations of the dark skin pigment melanin in the skin. They typically occur on the face and shoulders, and are more common in light-skinned people. They are also a well-recognised genetic trait and become more dominant during sun-exposure.

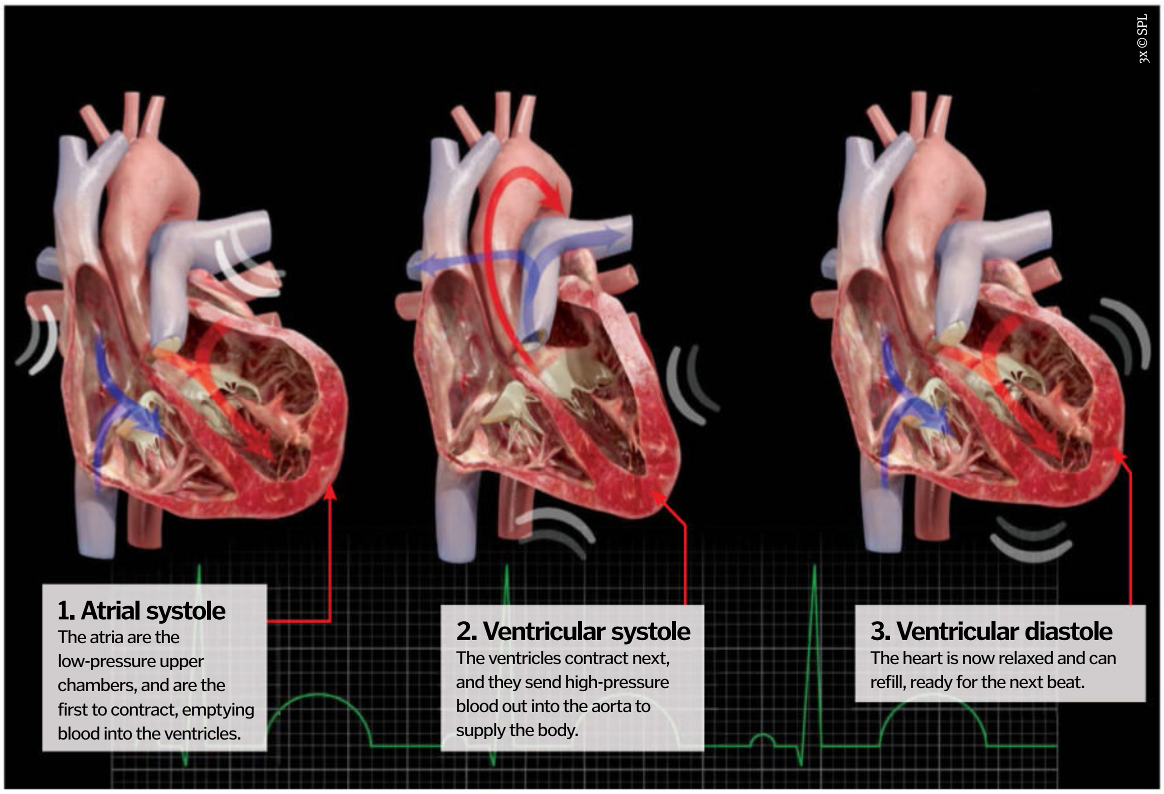
© Klaus D. Peter, Wiehl, Germany

37 WHAT IS A WART?

Warts are small, rough, round growths of the skin caused by the human papilloma virus. There are many different types which can occur in different parts of the body, and they can be contagious. They commonly occur on the hands, but can also come up anywhere from the genitals to the feet!

38 WHY DO I TWITCH IN MY SLEEP?

This is common and known in the medical world as a myoclonic twitch. Although some researchers say these twitches are associated with stress or caffeine use, they are likely to be a natural part of the sleep process. If it happens to you, it's perfectly normal.



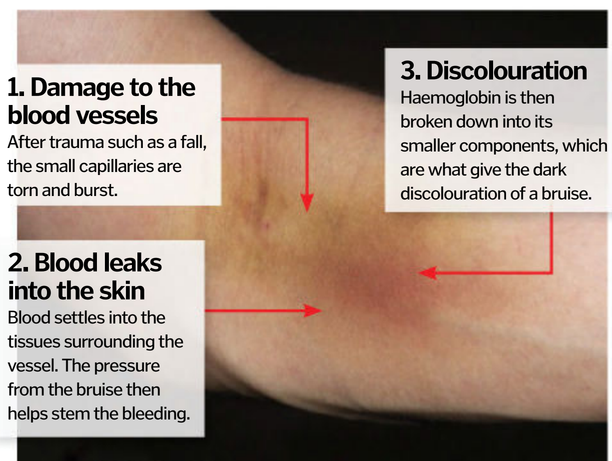
39 What triggers the heart and keeps it beating?

The heart keeps itself beating. The sinoatrial node (SAN) is in the wall of the right atrium of the heart, and is where the heartbeat starts. These beats occur due to changes in electrical currents as calcium, sodium and potassium move across membranes. The heart can beat at a rate of 60 beats per minute constantly if left alone. However – we often need it to go faster. The sympathetic nervous system sends rapid signals from the brain to stimulate the heart to beat faster when we need it to – in 'fight or flight' scenarios. If the SAN fails, a pacemaker can send artificial electrical signals to keep the heart going.

Definitions
Systole = contraction
Diastole = relaxation

40 Why do bruises go purple or yellow?

A bruise forms when capillaries under the skin leak and allow blood to settle in the surrounding tissues. The haemoglobin in red blood cells is broken down, and these by-products give a dark yellow, brown or purple discolouration depending on the volume of blood and colour of the overlying skin. Despite popular belief, you cannot age a bruise – different people's bruises change colour at different rates.



41 Why does cutting onions make us cry?


© Lali Masriera

Onions make your eyes water due to their expulsion of an irritant gas once cut. This occurs as when an onion is cut with a knife, many of its internal cells are broken down, allowing enzymes to break down amino acid sulphoxides and generate sulphenic acids. These sulphenic acids are then rearranged by another enzyme and, as a direct consequence, syn-propanethial-S-oxide gas is produced, which is volatile. This volatile gas then diffuses in the air surrounding the onion, eventually reaching the eyes of the cutter, where it proceeds to activate sensory neurons and create a stinging sensation. As such, the eyes then follow protocol and generate tears from their tear glands in order to dilute and remove the irritant. Interestingly, the volatile gas generated by cutting onions can be largely mitigated by submerging the onion in water prior to or midway through cutting, with the liquid absorbing much of the irritant.

44 Why do more men go bald than women?

'Simple' male pattern baldness is due to a combination of genetic factors and hormones. The most implicated hormone is testosterone, which men have high levels of but women have low levels of, so they win (or lose?) in this particular hormone contest!

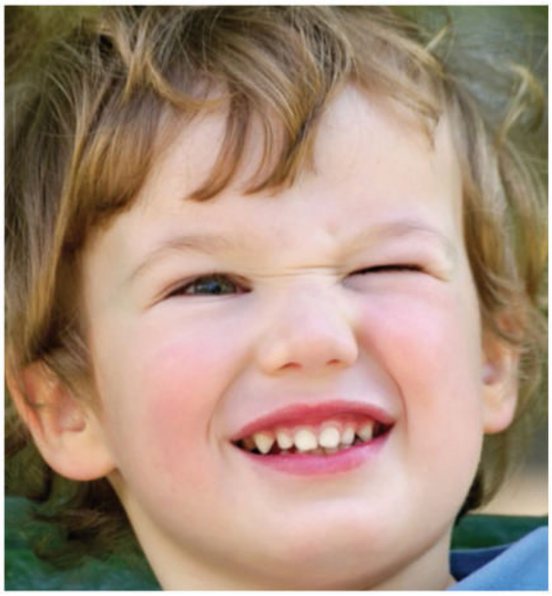

© David Benbennick

42 What is the little triangle shape on the side of the ear?

This is the tragus. It serves no major function that we know of, but it may help to reflect sounds into the ear to improve hearing.

43 When we're tired, why do we get bags under our eyes?

Blood doesn't circulate around your body as efficiently when you're asleep so excess water can pool under the eyes, making them puffy. Fatigue, nutrition, age and genes also cause bags.



45 Why do we blink?

Blinking helps keep your eyes clean and moist. Blinking spreads secretions from the tear glands (lacrimal fluids) over the surface of the eyeball, keeping it moist and also sweeping away small particles such as dust.

46 How come most people have one foot larger than the other?

Most people's feet are different sizes – in fact the two halves of most people's bodies are different! We all start from one cell, but as the cells multiply, genes give them varying characteristics.

47 Why do we get itchy?

Itching is caused by the release of a transmitter called histamine from mast cells which circulate in your body. These cells are often released in response to a stimulus, such as a bee sting or an allergic reaction. They lead to inflammation and swelling, and send impulses to the brain via nerves which causes the desire to itch.

48 Why do some hereditary conditions skip a generation?

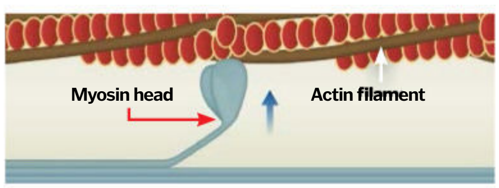
Genes work in pairs. Some genes are 'recessive' and if paired with a 'dominant' half, they won't shine through. However, if two recessive genes combine (one from your mother and one from your father), the recessive trait will show through.

49 Why do amputees sometimes still feel pain in their amputated limbs?

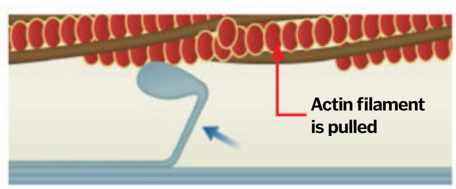
This is 'phantom limb pain' and can range from a mild annoyance to a debilitating pain. The brain can sometimes struggle to adjust to the loss of a limb, and it can still 'interpret' the limb as being there. Since the nerves have been cut, it interprets these new signals as pain. There isn't a surgical cure as yet, though time and special medications can help lessen the pain.

50 Which muscle produces the most powerful contraction relative to its size?

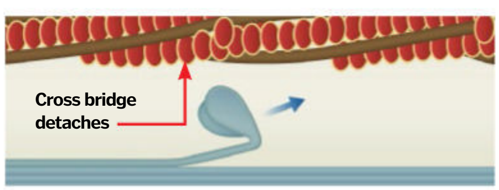
The gluteus maximus is the largest muscle and forms the bulk of your buttock. The heart (cardiac muscle) is the hardest-working muscle, as it is constantly beating and clearly can never take a break! However the strongest muscle based on weight is the masseter. This is the muscle that clenches the jaw shut – put a finger over the lowest, outer part of your jaw and clench your teeth and you'll feel it.



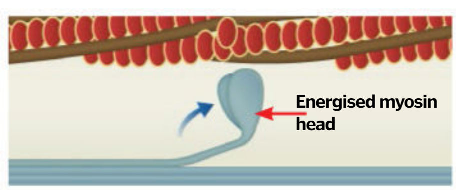
1. Taking the first step
Muscle contraction starts with an impulse received from the nerves supplying the muscle – an action potential. This action potential causes calcium ions to flood across the protein muscle fibres. The muscle fibres are formed from two key proteins: actin and myosin.



2. Preparation
The calcium binds to troponin which is a receptor on the actin protein. This binding changes the shape of tropomyosin, another protein which is bound to actin. These shape changes lead to the opening of a series of binding sites on the actin protein.



3. Binding
Now the binding sites are free on actin, the myosin heads forge strong bonds in these points. This leads to the contraction of the newly formed protein complex; when all of the proteins contract, the muscle bulk contracts.



4. Unbinding
When the energy runs out, the proteins lose their strong bonds and disengage, and from there they return to their original resting state.

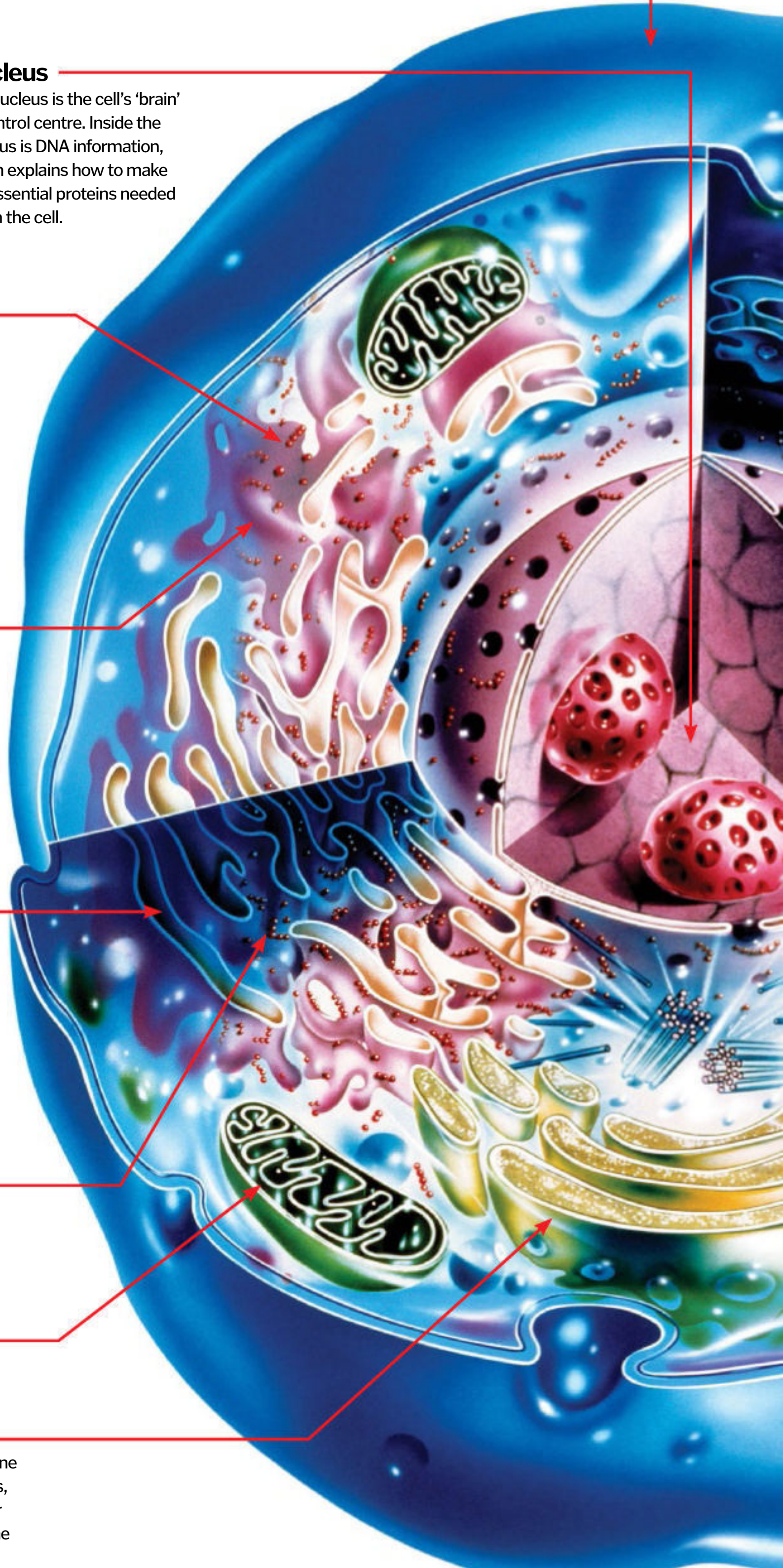
Cell structure explained

There are around 75 trillion cells in the human body, but what are they and how do they work?

Cells are life and cells are alive. You are here because every cell inside your body has a specific function and a very specialised job to do. There are many different types of cell, each one working to keep the body's various systems operating. A single cell is the smallest unit of living material in the body capable of life. When grouped together in layers or clusters, however, cells with similar jobs to do form tissue, such as skin or muscle. To keep these cells working, there are thousands of chemical reactions going on all the time.

All animal cells contain a nucleus, which acts like a control hub telling the cell what to do and contains the cell's genetic information (DNA). Most of the material within a cell is a watery, jelly-like substance called cytoplasm (cyto means cell), which circulates around the cell and is held in by a thin external membrane, which consists of two layers. Within the cytoplasm is a variety of structures called organelles, which all have different tasks, such as manufacturing proteins – the cell's key chemicals. One vital example of an organelle is a ribosome; these numerous structures can be found either floating around in the cytoplasm or attached to internal membranes. Ribosomes are crucial in the production of proteins from amino acids.

In turn, proteins are essential to building your cells and carrying out the biochemical reactions the body needs in order to grow and develop and also to repair itself and heal.



Cell membrane
Surrounding and supporting each cell is a plasma membrane that controls everything that enters and exits.

Nucleus
The nucleus is the cell's 'brain' or control centre. Inside the nucleus is DNA information, which explains how to make the essential proteins needed to run the cell.

Ribosomes
These tiny structures make proteins and can be found either floating in the cytoplasm or attached like studs to the endoplasmic reticulum, which is a conveyor belt-like membrane that transports proteins around the cell.

Endoplasmic reticulum
The groups of folded membranes (canals) connecting the nucleus to the cytoplasm are called the endoplasmic reticulum (ER). If studded with ribosomes the ER is referred to as 'rough' ER; if not it is known as 'smooth' ER. Both help transport materials around the cell but also have differing functions.

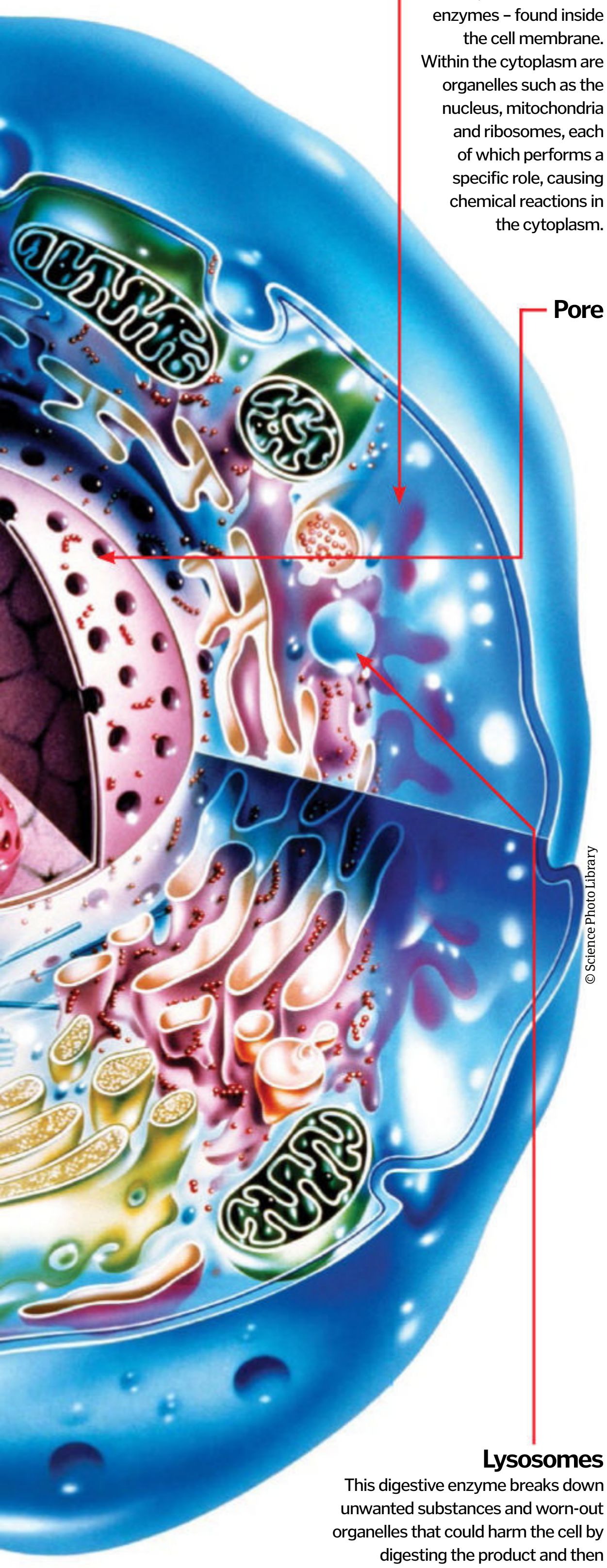
Smooth endoplasmic reticulum

Rough endoplasmic reticulum (studded with ribosomes)

Mitochondria
These organelles supply cells with the energy necessary for them to carry out their functions. The amount of energy used by a cell is measured in molecules of adenosine triphosphate (ATP). Mitochondria use the products of glucose metabolism as fuel to produce the ATP.

Golgi body
Another organelle, the Golgi body is one that processes and packages proteins, including hormones and enzymes, for transportation either in and around the cell or out towards the membrane for secretion outside the cell where it can enter the bloodstream.

Cell anatomy



Cytoplasm
This is the jelly-like substance – made of water, amino acids and enzymes – found inside the cell membrane. Within the cytoplasm are organelles such as the nucleus, mitochondria and ribosomes, each of which performs a specific role, causing chemical reactions in the cytoplasm.

Pore

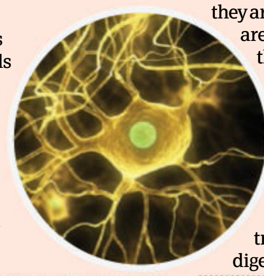
Lysosomes
This digestive enzyme breaks down unwanted substances and worn-out organelles that could harm the cell by digesting the product and then ejecting it outside the cell.

© Science Photo Library

Types of human cell

So far around 200 different varieties of cell have been identified, and they all have a very specific function to perform. Discover the main types and what they do…

NERVE CELLS

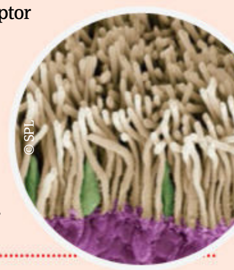


The cells that make up the nervous system and the brain are nerve cells or neurons. Electrical messages pass between nerve cells along long filaments called axons. To cross the gaps between nerve cells (the synapse) that electrical signal is converted into a chemical signal. These cells enable us to feel sensations, such as pain, and they also enable us to move.

BONE CELLS

The cells that make up bone matrix – the hard structure that makes bones strong – consist of three main types. Your bone mass is constantly changing and reforming and each of the three bone cells plays its part in this process. First the osteoblasts, which come from bone marrow, build up bone mass and structure. These cells then become buried in the matrix at which point they become known as osteocytes. Osteocytes make up around 90 per cent of the cells in your skeleton and are responsible for maintaining the bone material. Finally, while the osteoblasts add to bone mass, osteoclasts are the cells capable of dissolving bone and changing its mass.

PHOTORECEPTOR CELLS

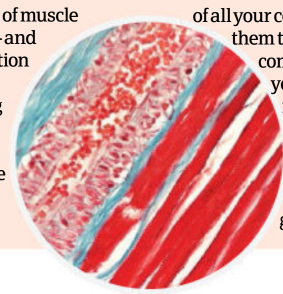


The cones and rods on the retina at the back of the eye are known as photoreceptor cells. These contain light-sensitive pigments that convert the image that enters the eye into nerve signals, which the brain interprets as pictures. The rods enable you to perceive light, dark and movement, while the cones bring colour to your world.

LIVER CELLS

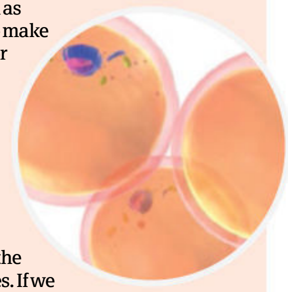
The cells in your liver are responsible for regulating the composition of your blood. These cells filter out toxins as well as controlling fat, sugar and amino acid levels. Around 80 per cent of the liver's mass consists of hepatocytes, which are the liver's specialised cells that are involved with the production of proteins and bile.

MUSCLE CELLS



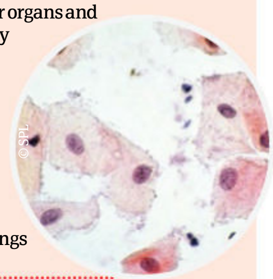
There are three types of muscle cell – skeletal, cardiac and smooth – and each differs depending on the function it performs and its location in the body. Skeletal muscles contain long fibres that attach to bone. When triggered by a nerve signal, the muscle contracts and pulls the bone with it, making you move. We can control skeletal muscles because they are voluntary. Cardiac muscles, meanwhile, are involuntary, which is fortunate because they are used to keep your heart beating. Found in the walls of the heart, these muscles create their own stimuli to contract without input from the brain. Smooth muscles, which are pretty slow and also involuntary, make up the linings of hollow structures such as blood vessels and your digestive tract. Their wave-like contraction aids the transport of blood around the body and the digestion of food.

FAT CELLS



These cells – also known as adipocytes or lipocytes – make up your adipose tissue, or body fat, which can cushion, insulate and protect the body. This tissue is found beneath your skin and also surrounding your other organs. The size of a fat cell can increase or decrease depending on the amount of energy it stores. If we gain weight the cells fill with more watery fat, and eventually the number of fat cells will begin to increase. There are two types of adipose tissue: white and brown. The white adipose tissue stores energy and insulates the body by maintaining body heat. The brown adipose tissue, on the other hand, can actually create heat and isn't burned for energy – this is why animals are able to hibernate for months on end without food.

EPITHELIAL CELLS



Epithelial cells make up the epithelial tissue that lines and protects your organs and constitute the primary material of your skin. These tissues form a barrier between the precious organs and unwanted pathogens or other fluids. As well as covering your skin, you'll find epithelial cells inside your nose, around your lungs and in your mouth.

RED BLOOD CELLS

Unlike all the other cells in your body, your red blood cells (also known as erythrocytes) do not contain a nucleus. You are topped up with around 25 trillion red blood cells – that's a third of all your cells, making them the most common cell in your body. Formed in the bone marrow, these cells are important because they carry oxygen to all the tissues in your body. Oxygen is carried in haemoglobin, a pigmented protein that gives blood cells their red colour.

Inside a nucleus

Dissecting the control centre of a cell

Surrounded by cytoplasm, the nucleus contains a cell's DNA and controls all of its functions and processes such as movement and reproduction.

There are two main types of cell: eukaryotic and prokaryotic. Eukaryotic cells contain a nucleus while prokaryotic do not. Some eukaryotic cells have more than one nucleus – called multinucleate cells – occurring when fusion or division creates two or more nuclei.

At the heart of a nucleus you'll find the nucleolus; this particular area is essential in the formation of ribosomes. Ribosomes are responsible for making proteins out of amino acids which take care of growth and repair.

Being so important, the nucleus is the most protected part of the cell. In animal cells it is always located near its centre and away from the membrane to ensure it has the maximum cushioning. As well as the jelly-like cytoplasm around it, the nucleus itself is filled with nucleoplasm, a viscous liquid which maintains its structural integrity.

Conversely, in plant cells, the nucleus is more sporadically placed. This is due to the larger vacuole in a plant cell and the added protection that is granted by a cell wall.

Central command

Take a peek at what's happening inside the 'brain' of a eukaryotic cell

1 Nuclear pore
These channels control the movement of molecules between the nucleus and cytoplasm.

2 Nuclear envelope
Acts as a wall to protect the DNA within the nucleus and regulates cytoplasm access.

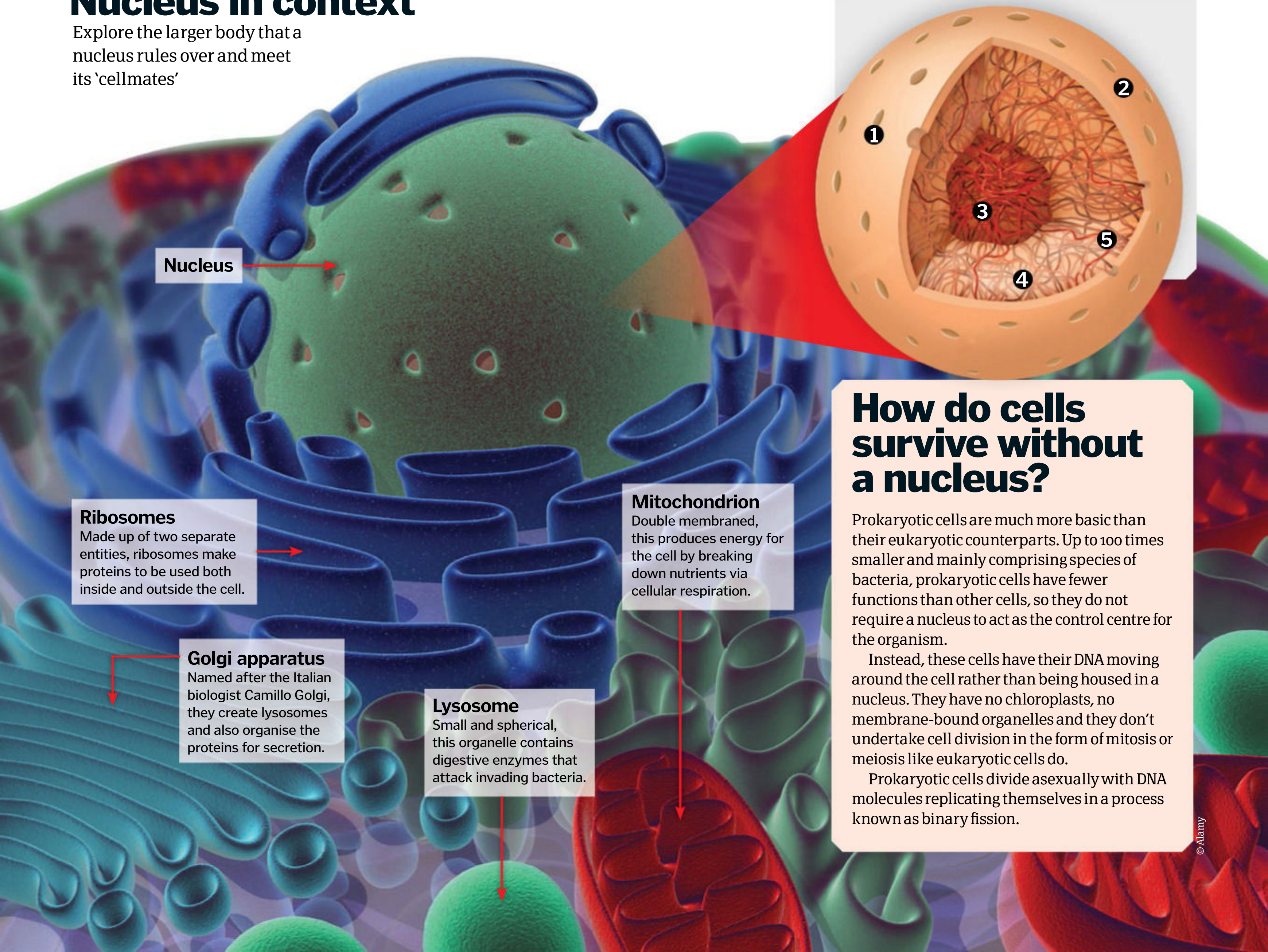
3 Nucleolus
Made up of protein and RNA, this is the heart of the nucleus which manufactures ribosomes.

4 Nucleoplasm
This semi-liquid, semi-jelly material surrounds the nucleolus and keeps the organelle's structure.

5 Chromatin
Produces chromosomes and aids cell division by condensing DNA molecules.

Nucleus in context

Explore the larger body that a nucleus rules over and meet its 'cellmates'

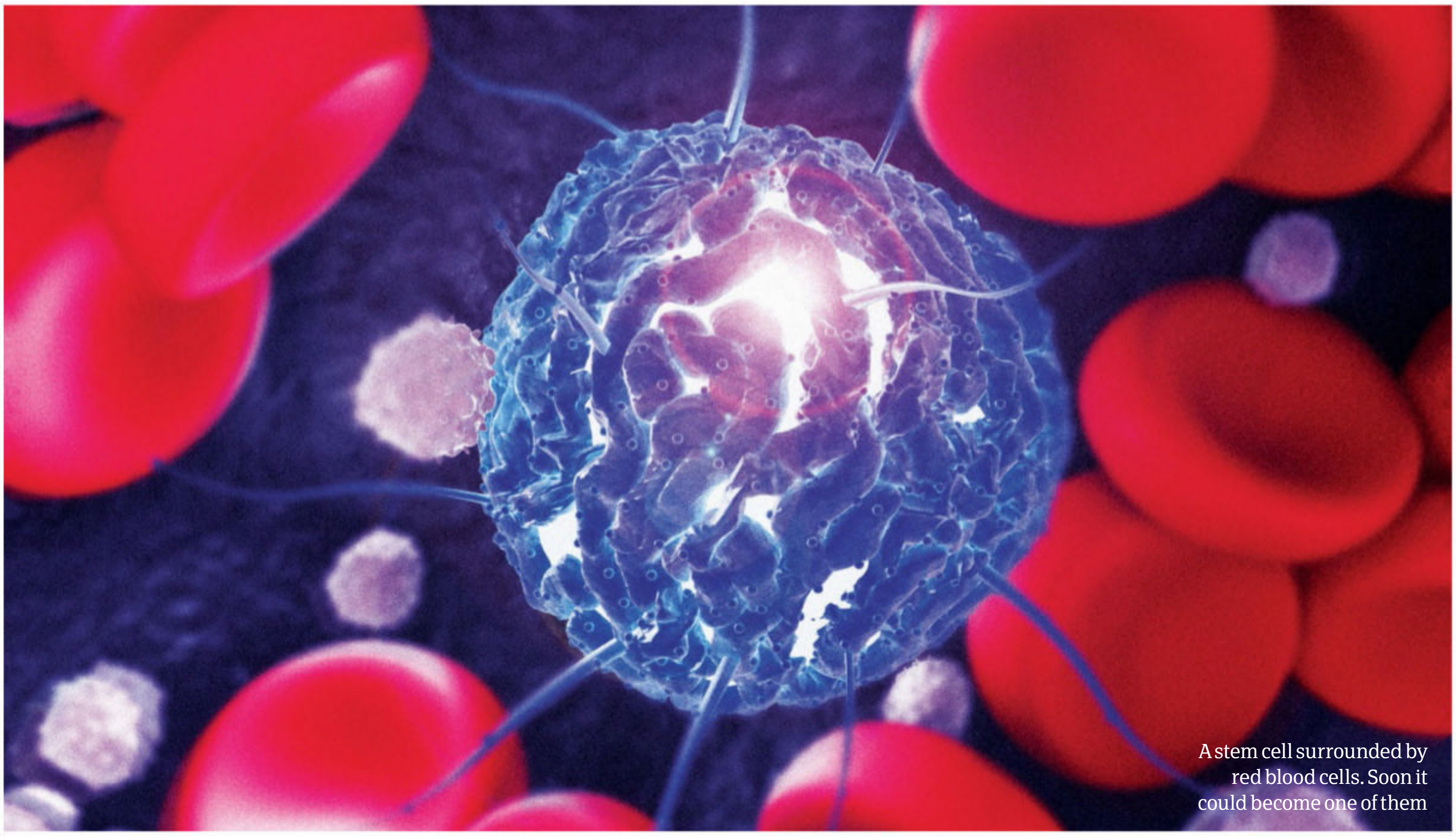


How do cells survive without a nucleus?

Prokaryotic cells are much more basic than their eukaryotic counterparts. Up to 100 times smaller and mainly comprising species of bacteria, prokaryotic cells have fewer functions than other cells, so they do not require a nucleus to act as the control centre for the organism.

Instead, these cells have their DNA moving around the cell rather than being housed in a nucleus. They have no chloroplasts, no membrane-bound organelles and they don't undertake cell division in the form of mitosis or meiosis like eukaryotic cells do.

Prokaryotic cells divide asexually with DNA molecules replicating themselves in a process known as binary fission.



A stem cell surrounded by red blood cells. Soon it could become one of them

What are stem cells?

Understand how these building blocks bring new life

Stem cells are incredibly special because they have the potential to become any kind of cell in the body, from red blood cells to brain cells. They are essential to life and growth, as they repair tissues and replace dead cells. Skin, for example, is constantly replenished by skin stem cells.

Stem cells begin their life cycle as generic, featureless cells that don't contain tissue-specific structures, such as the ability to carry oxygen. Stem cells become specialised through a process called differentiation. This is triggered by signals inside and outside the cell. Internal signals come from strands of DNA that carry information for all cellular structures, while external signals include chemicals from nearby cells. Stem cells can replicate many times – known as proliferation – while others such as nerve cells don't divide at all.

There are two stem cell types, as Professor Paul Fairchild, co-director of the Oxford Stem Cell Institute at Oxford Martin School explains: "Adult stem cells are multipotent, which means they are able to produce numerous cells that are loosely related, such as stem cells in the bone marrow can generate cells that make up the blood," he says. "In contrast, pluripotent stem cells, found within developing embryos, are able to make any one of the estimated 210 cell types that make up the human body."

This fascinating ability to transform and divide has made stem cells a rich source for medical research. Once their true potential has been harnessed, they could be used to treat a huge range of diseases and disabilities.

Cloning cells

Scientists can reprogram cells to forget their current role and become pluripotent cells indistinguishable from early embryonic stem cells. Induced pluripotent stem cells (IPSCs) can be used to take on the characteristics of nearby cells.

IPSCs are more reliable than stem cells grown from a donated embryo because the body is more likely to accept self-generated cells. IPSCs can treat degenerative conditions such as Parkinson's disease and baldness, which are caused by cells dying without being replaced. The IPSCs fill those gaps in order to restore the body's systems.

Professor Fairchild explains, "by deriving these cells from individuals with rare conditions, we are able to model the condition in the laboratory and investigate the effects of new drugs on that disease."

Your brain

The human brain is the most mysterious – and complex – entity in the known universe

It's a computer, a thinking machine, a pink organ, and a vast collection of neurons – but how does it work? The human brain is amazingly complex – in fact, more complex than anything in the known universe. The brain effortlessly consumes power, stores memories, processes thoughts, and reacts to danger.

In some ways, the human brain is like a car engine. The fuel – which could be the sandwich you had for lunch or a sugar doughnut for breakfast – causes neurons to fire in a logical sequence and to bond with other neurons. This combination of neurons occurs incredibly fast, but the chain reaction might help you compose a symphony or recall entire passages of a book, help you pedal a bike or write an email to a friend.

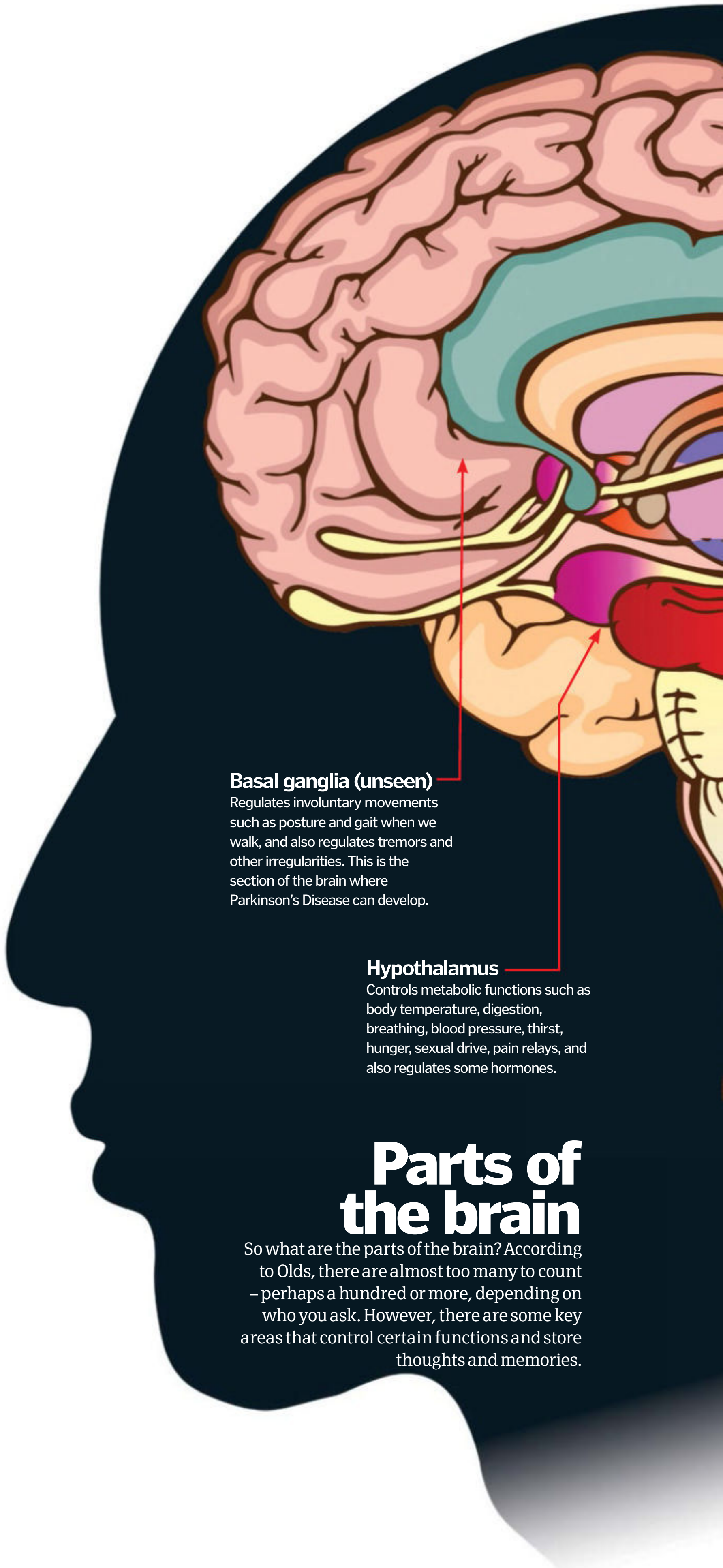
Scientists are just beginning to understand how these brain neurons work – they have not figured out how they trigger a reaction when you touch a hot stove, for example, or why you can re-generate brain cells when you work out at the gym.

The connections inside a brain are very similar to the internet – the connections are constantly exchanging information. Yet, even the internet is rather simplistic when compared to neurons. There are ten to 100 neurons, and each one makes thousands of connections. This is how the brain processes information, or determines how to move an arm and grip a surface. These calculations, perceptions, memories, and reactions occur almost instantaneously, and not just a few times per minute, but millions. According to Jim Olds, research director with George Mason University, if the internet were as complex as our solar system, then the brain would be as complex as our galaxy. In other words, we have a lot to learn. Science has not given up trying, and has made recent discoveries about how we adapt, learn new information, and can actually increase brain capability.

In the most basic sense, our brain is the centre of all input and outputs in the human body. Dr Paula Tallal, a co-director of neuroscience at Rutgers University, says the brain is constantly processing sensory information – even from infancy. "It's easiest to think of the brain in terms of inputs and outputs," says Tallal. "Inputs are sensory information, outputs are how our brain organises that information and controls our motor systems."

Tallal says one of the primary functions of the brain is in learning to predict what comes next. In her research for Scientific Learning, she has found that young children enjoy having the same book read to them again and again because that is how the brain registers acoustic cues that form into phonemes (sounds) to become spoken words.

"We learn to put things together so that they become smooth sequences," she says. These smooth sequences are observable in the brain, interpreting

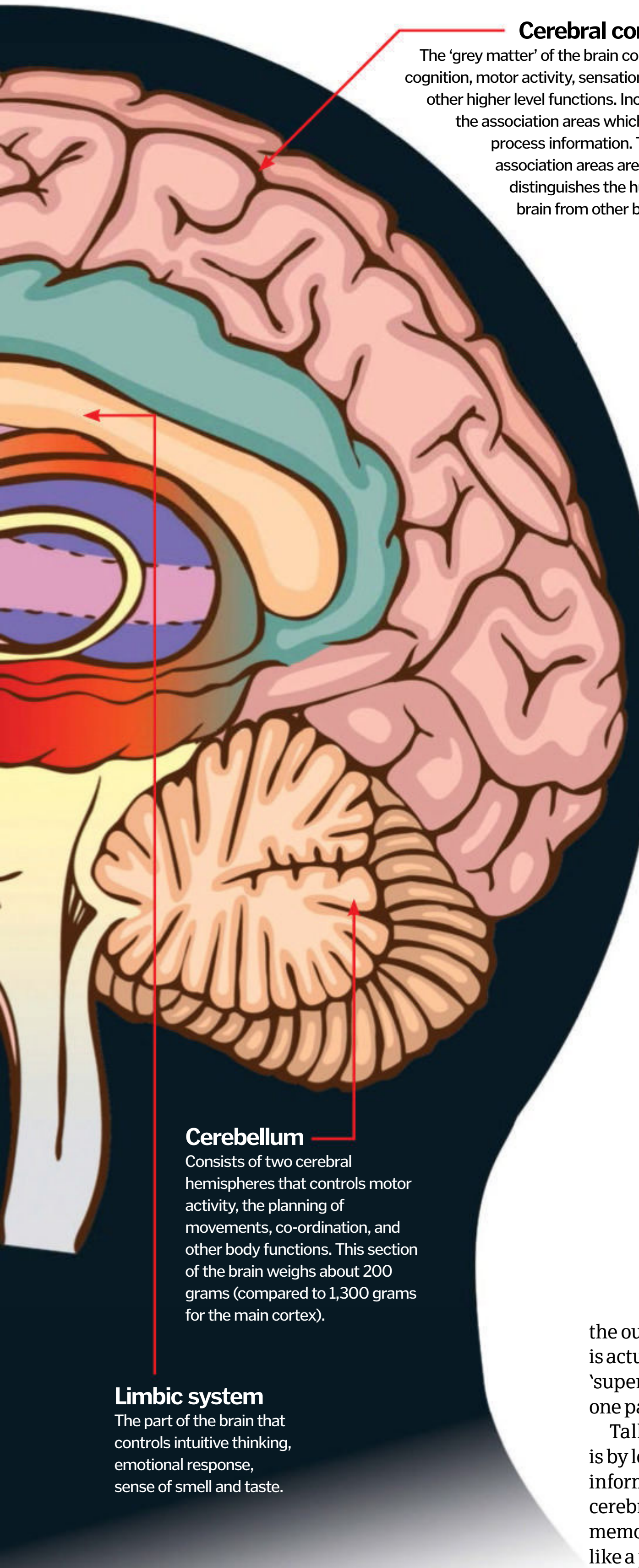


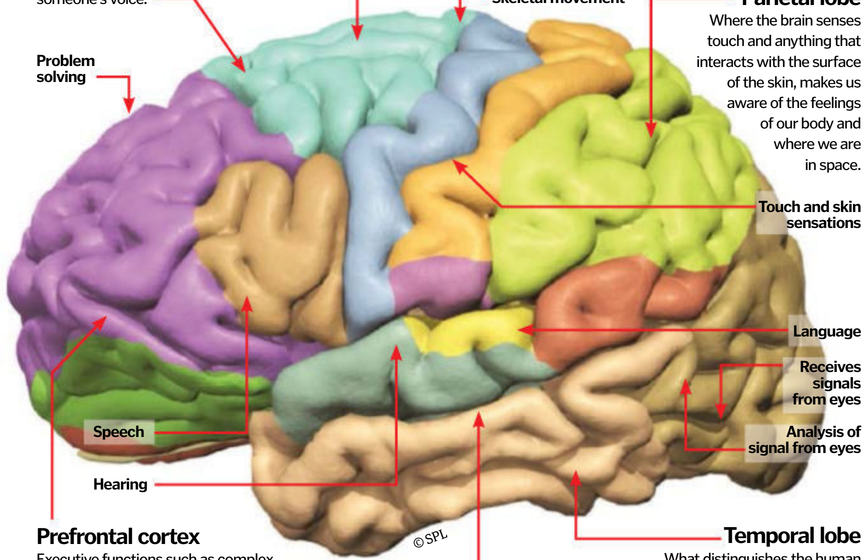
Parts of the brain

So what are the parts of the brain? According to Olds, there are almost too many to count – perhaps a hundred or more, depending on who you ask. However, there are some key areas that control certain functions and store thoughts and memories.

Functions of the cerebral cortex

The cerebral cortex is the wrinkling part of our brain that shows up when you see pictures of the brain





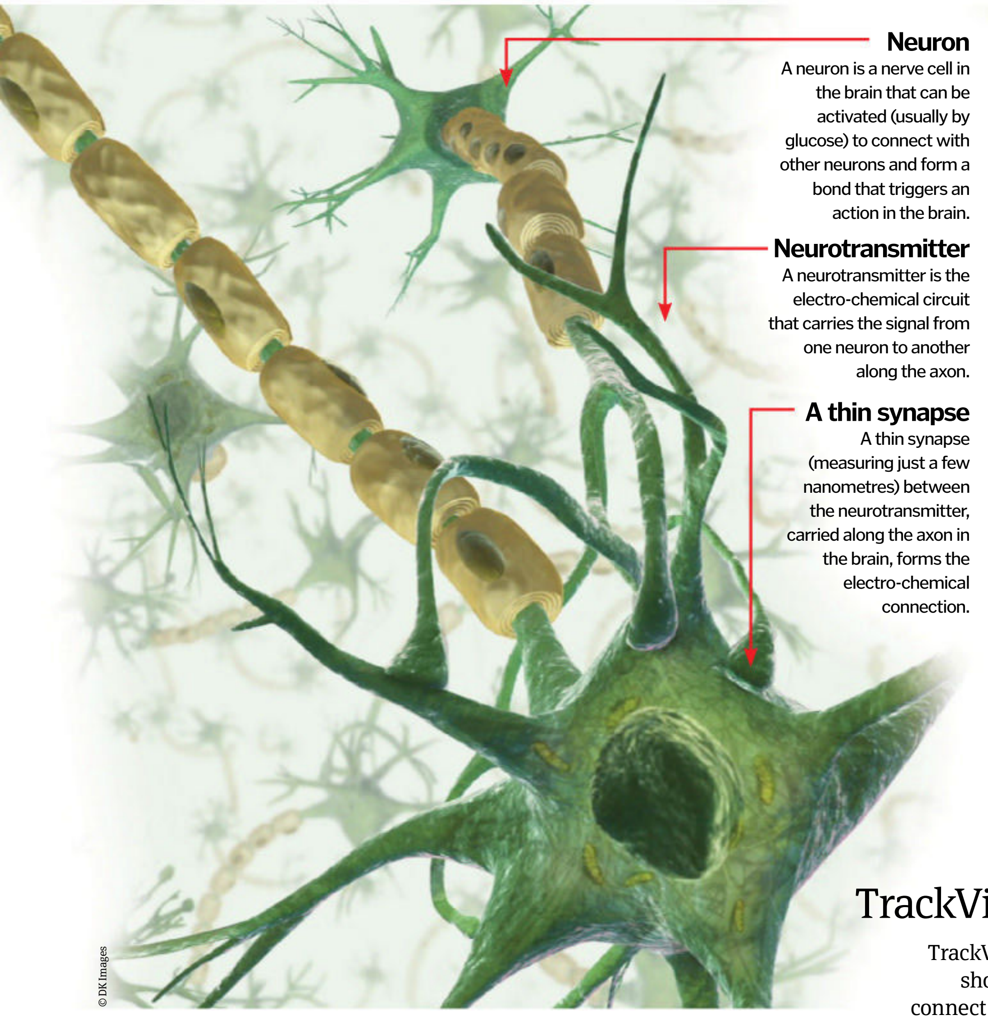
"In a sense, the main function of the brain is in ordering information – interpreting the outside world and making sense of it"

the outside world and making sense of it. The brain is actually a series of interconnected 'superhighways' or pathways that move 'data' from one part of the body to another.

Tallal says another way to think about the brain is by lower and upper areas. The spinal cord moves information up to the brain stem, then up into the cerebral cortex which controls thoughts and memories. Interestingly, the brain really does work like a powerful computer in determining not only movements but registering memories that can be quickly recalled.

According to Dr Robert Melillo, a neurologist and the founder of the Brain Balance Centers (www.brainbalancecenters.com), the brain actually predetermines actions and calculates the results about a half-second before performing them (or even faster in some cases). This means that when you reach out to open a door, your brain has already predetermined how to move your elbow and clasp your hand around the door handle – maybe even simulated this movement more than once, before you even actually perform the action.

Another interesting aspect to the brain is that there are some voluntary movements and some involuntary. Some sections of the brain might control a voluntary movement – such as patting your knee to a beat. Another section controls involuntary movements, such as the gait of your walk – which is passed down from your parents. Reflexes, long-term memories, the pain reflex – these are all aspects that are controlled by sections in the brain.



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Neurons explained

Neurons fire like electrical circuits

Neurons are a kind of cell in the brain (humans have many cells in the body, including fat cells, kidney cells, and gland cells). A neuron is essentially like a hub that works with nearby neurons to generate an electrical and chemical charge. Dr Likosky of the Swedish Medical Institute says another way of thinking about neurons is that they are like a basketball and the connections (called axons) are like electrical wires that connect to other neurons. This creates a kind of circuit in the human body. Tallal explained that input from the five senses in the body cause neurons to fire.

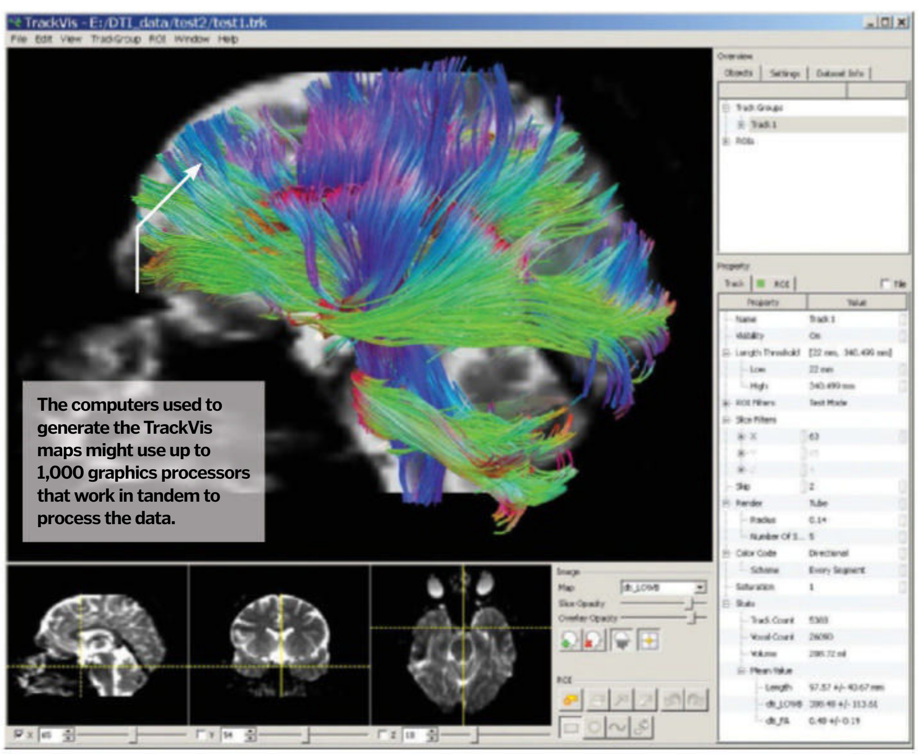
"The more often a collection of neurons are stimulated together in time, the more likely they are to bind together and the easier and easier it becomes for that pattern of neurons to fire in synchrony as well as sequentially," says Tallal.

Brain maps

TrackVis generates unique maps of the brain

TrackVis is a free program used by neurologists to see a map of the brain that shows the fibre connections. On every brain, these neural pathways help connect one part of the brain to another so that a feeling you experience in one part of the brain can be transmitted and processed by another part of the brain (one that may decide the touch is harmful or pleasant). TrackVis uses fMRI readings on actual patients to generate the colourful and eye-catching images. To construct the maps, the program can take several hours to determine exactly how the fibres are positioning in the brain.

"The brain – a fragile organ that weighs about 1,500 grams"



The computers used to generate the TrackVis maps might use up to 1,000 graphics processors that work in tandem to process the data.

What is my brain like?

If you could hold it in your hand…

In pictures that we are all accustomed to seeing, the human brain often looks pink and spongy, with a sheen of slime. According to Dr William Likosky, a neurologist at the Swedish Medical Institute (www.swedish.org), the brain is actually quite different from what most people would immediately think it is.

Likosky described the brain as being not unlike feta cheese in appearance – a fragile organ that weighs about 1,500 grams and sags almost like a bag filled with water.

In the skull, the brain is highly protected and has hard tissue, but most of the fatty tissue in the brain – which helps pass chemicals and other substances through membranes – is considerably more delicate.

How do nerves work?

Nerves carry signals throughout the body – a chemical superhighway

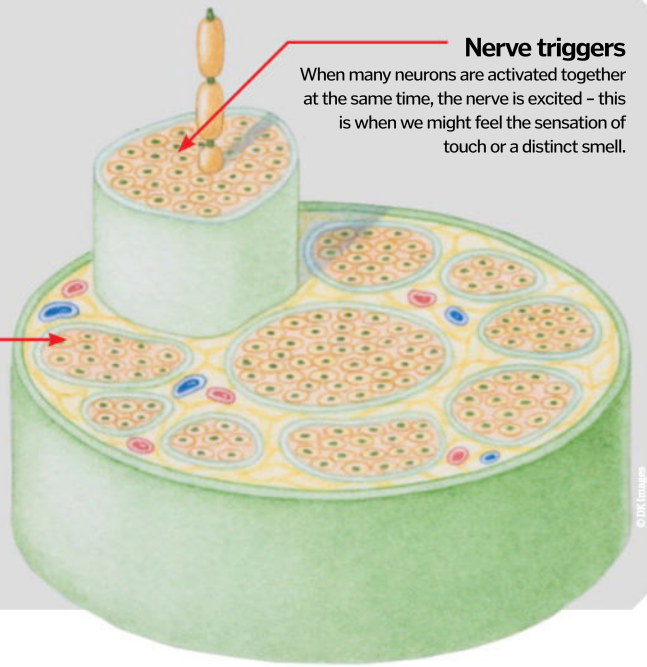
Nerves are the transmission cables that carry brain waves in the human body, says Sol Diamond, an assistant professor at the Thayer School of Engineering at Dartmouth. According to Diamond, nerves communicate these signals from one point to another, whether from your toenail up to your brain or from the side of your head.

Nerve transmissions

Some nerve transmissions travel great distances through the human body, others travel short distances – both use a de-polarisation to create the circuit. De-polarisation is like a wound-up spring that releases stored energy once it is triggered.

Nerve triggers

When many neurons are activated together at the same time, the nerve is excited – this is when we might feel the sensation of touch or a distinct smell.



Myelinated and un-mylinated

Some nerves are myelinated (or insulated) with fatty tissue that appears white and forms a slower connection over a longer distance. Others are un-myelinated and are un-insulated. These nerves travel shorter distances.

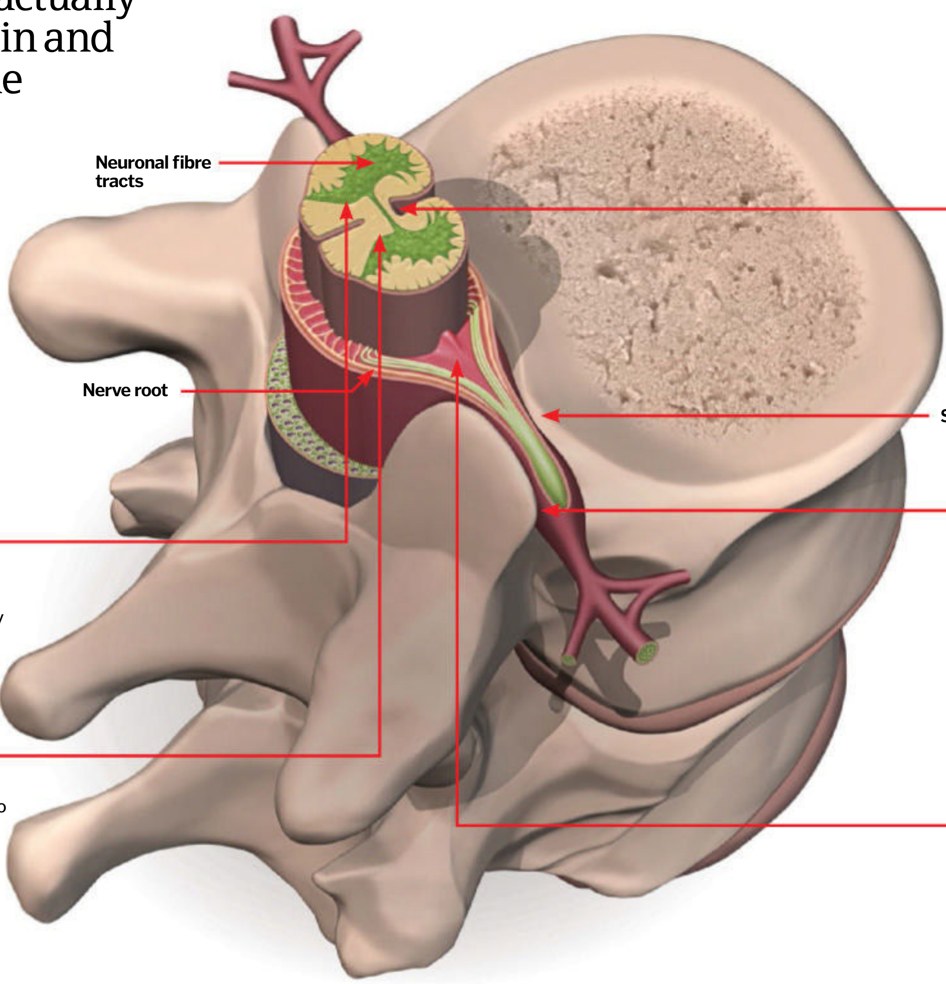
What does the spinal cord do?

The spinal cord actually is part of the brain and plays a major role

Scientists have known for the past 100 years or so that the spinal cord is actually part of the brain. According to Melillo, while the brain has grey matter on the outside (protected by the skull) and protected white matter on the inside, the spinal cord is the reverse: the grey matter is inside the spinal cord and the white matter is outside.

Spinal cord core

In the core of the spinal cord, grey matter – like the kind in the outer layer of the brain – is for processing nerve cells such as touch, pain and movement.



Grey matter cells

Grey matter cells in the spinal cord cannot regenerate, which is why people with a serious spinal cord injury cannot recover over a period of time. White matter cells can re-generate.

Neurogenesis

According to Tallal, by repeating brain activities such as memorisation and pattern recognition, you can grow new brain cells in the spinal cord and brain.

White matter cells

White matter cells in the spinal cord carry the electro-chemical pulses up to the brain. For example, when you are kicked in the shin, you feel the pain in the shin and your brain then tells you to move your hand to cover that area.

Neuroplasticity

In the spinal cord and in the brain, cells can rejuvenate over time when you exercise and become strengthened. This process is called neuroplasticity.

Inside the human eye

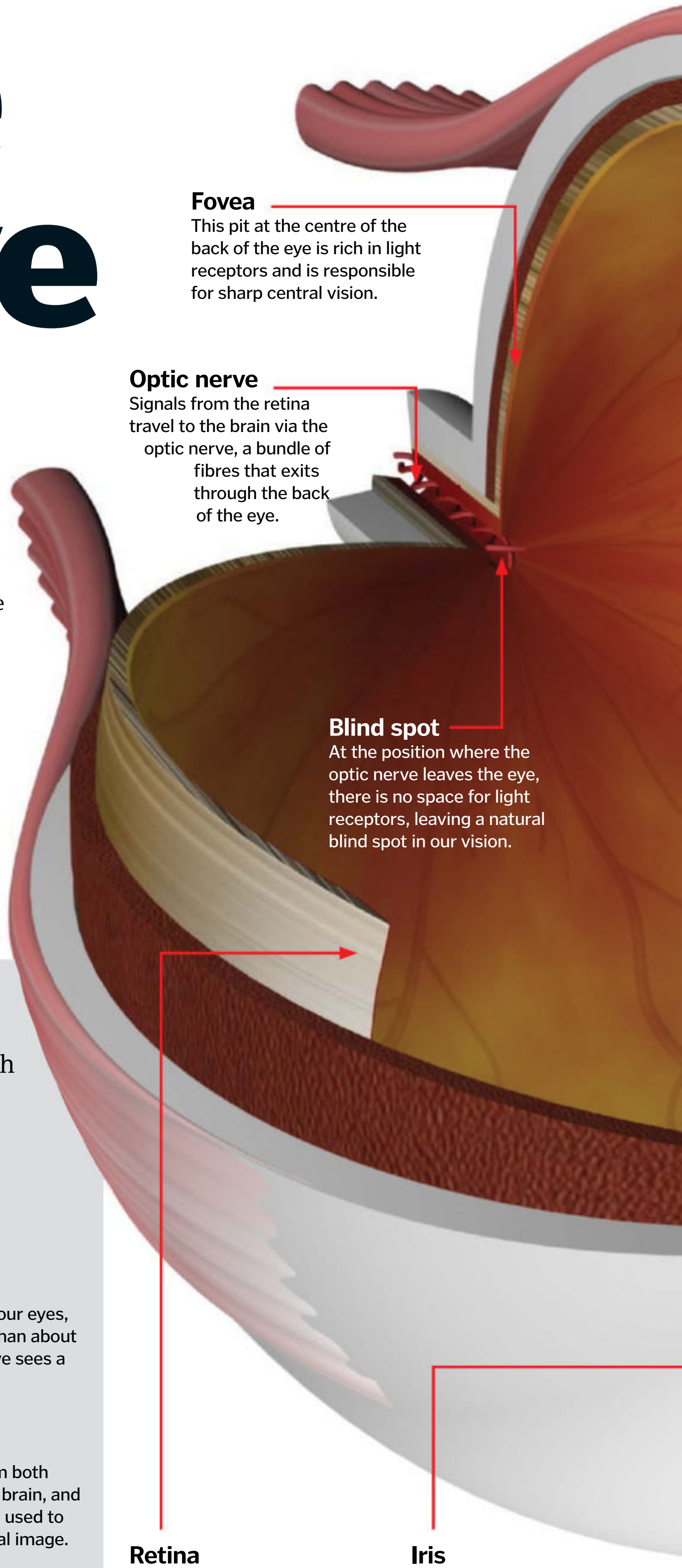
Uncovering one of the most complex constructs in the natural world

The structure of the human eye is so complex that it's hard to believe that it's not the product of intelligent design. But by looking at the eyes of other animals, scientists have shown that it evolved very gradually from a simple light-dark sensor over the course of around 100 million years.

It functions in a very similar way to a camera, with an opening through which the light enters, a lens for focusing and a light-sensitive membrane at the back.

The amount of light that enters the eye is controlled by the circular and radial muscles in the iris, which contract and relax to alter the size of the pupil. The light first passes through a tough protective sheet called the cornea, and then moves into the lens. This adjustable structure bends the light, focusing it down to a point on the retina, at the back of the eye.

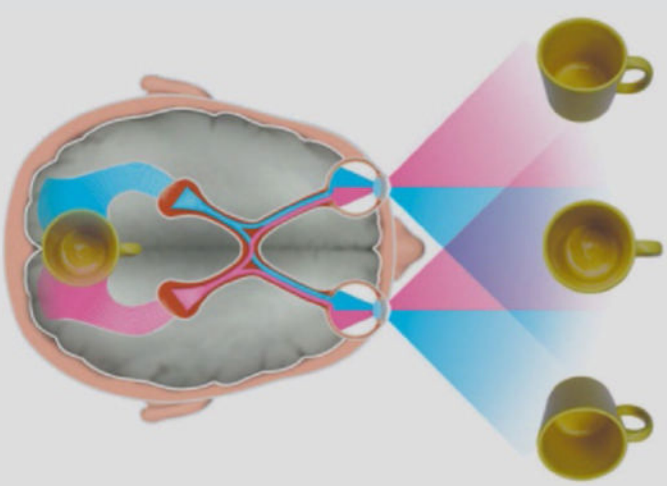
The retina is covered in millions of light-sensitive receptors known as rods and cones. Each receptor contains pigment molecules, which change shape when they are hit by light, triggering an electrical message that travels to the brain via the optic nerve.



Seeing in three dimensions

Each eye sees a slightly different image, allowing the brain to perceive depth

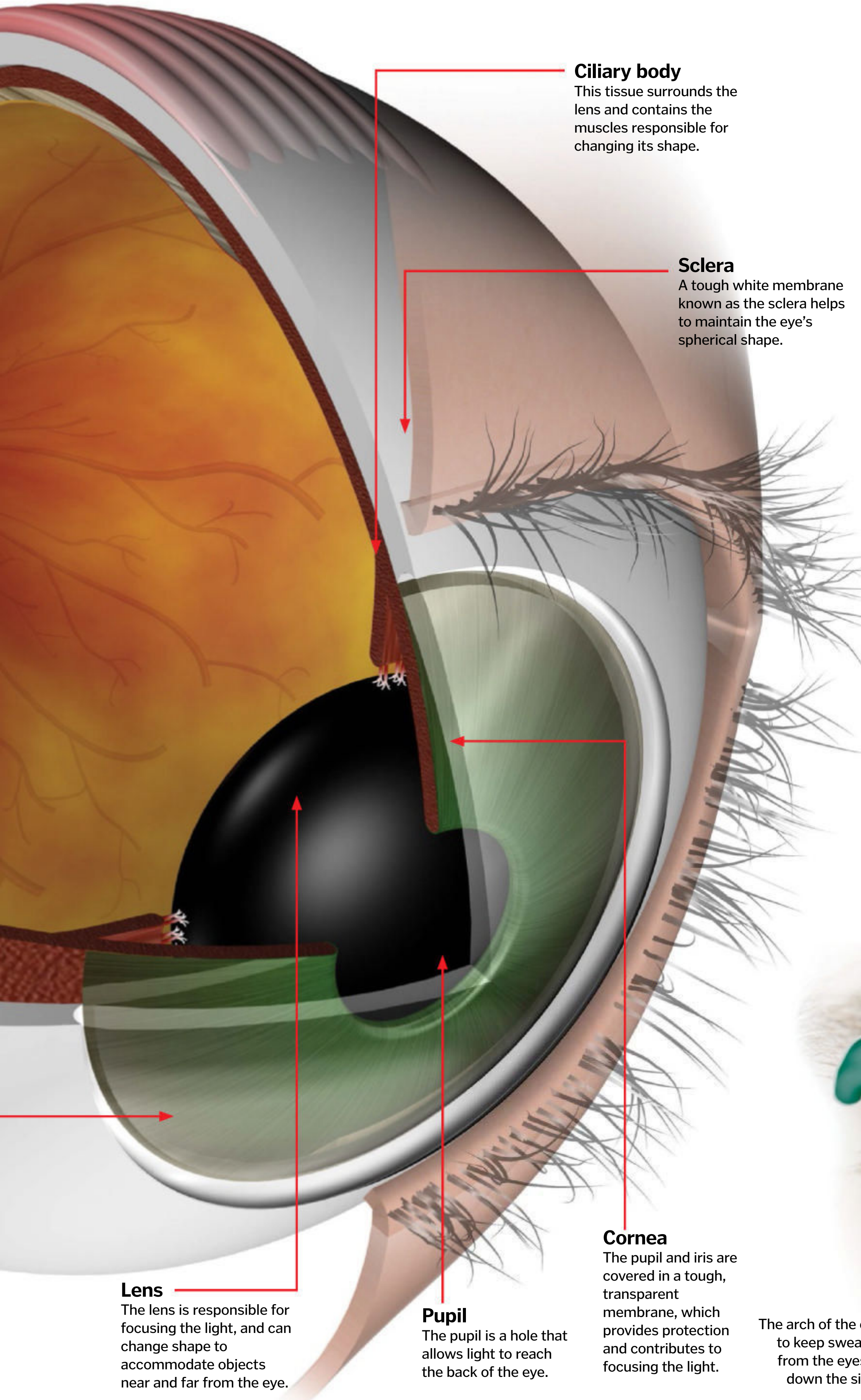
Our eyes are only able to produce two-dimensional images, but with some clever processing, the brain is able to build these flat pictures into a three-dimensional view. Our eyes are positioned about five centimetres (two inches) apart, so each sees the world from a slightly different angle. The brain compares the two pictures, using the differences to create the illusion of depth.



Individual image
Due to the positioning of our eyes, when objects are closer than about 5.5m (18ft) away, each eye sees a slightly different angle.

Combined image
The incoming signals from both eyes are compared in the brain, and the subtle differences are used to create a three-dimensional image.

Try it for yourself
By holding your hand in front of your face and closing one eye at a time, it is easy to see the different 2D views perceived by each eye.



Ciliary body
This tissue surrounds the lens and contains the muscles responsible for changing its shape.

Sclera
A tough white membrane known as the sclera helps to maintain the eye's spherical shape.

Lens
The lens is responsible for focusing the light, and can change shape to accommodate objects near and far from the eye.

Pupil
The pupil is a hole that allows light to reach the back of the eye.

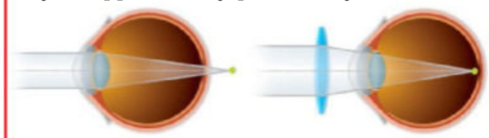
Cornea
The pupil and iris are covered in a tough, transparent membrane, which provides protection and contributes to focusing the light.

Vision problems

The most common problems with our eyesight

Farsightedness (hyperopia)

If the eye is too short, the cornea is too flat, or if the lens sits too far back, incoming light is focused behind the retina, making nearby objects appear blurry, particularly in the dark.



Nearsightedness (myopia)

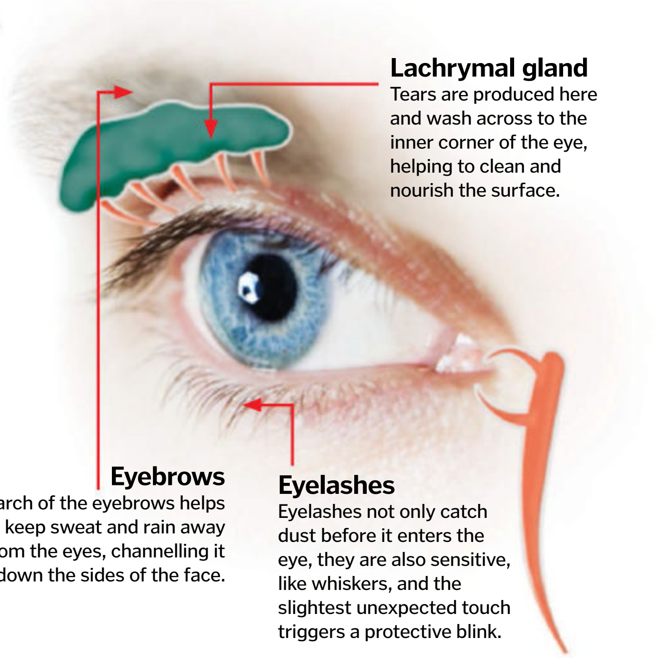
If the eye is too long, or the cornea and lens are too curved, the light is focused before it hits the back of the eye, and then starts to defocus again as it reaches the retina, making distant objects difficult to see.

Colour-blindness

This rare condition is often linked to a gene on the X-chromosome and occurs more commonly in men than in women. A defect in the cone cells of the eye reduces the number of colours that can be detected.

Protection

The eyes are shielded by several layers of protection. They are almost completely encased in bone at the back and insulated from shock by layers of muscle and connective tissue. The front is kept moist with tears and are constantly wiped by the blinking of the eyelids, while the hairs of the eyebrows and eyelashes catch any debris that might fall in.



Lachrymal gland
Tears are produced here and wash across to the inner corner of the eye, helping to clean and nourish the surface.

Eyebrows
The arch of the eyebrows helps to keep sweat and rain away from the eyes, channelling it down the sides of the face.

Eyelashes
Eyelashes not only catch dust before it enters the eye, they are also sensitive, like whiskers, and the slightest unexpected touch triggers a protective blink.

How ears work

The human ear performs a range of functions, sending messages to the brain when a sound is made while also providing your body with a sense of balance

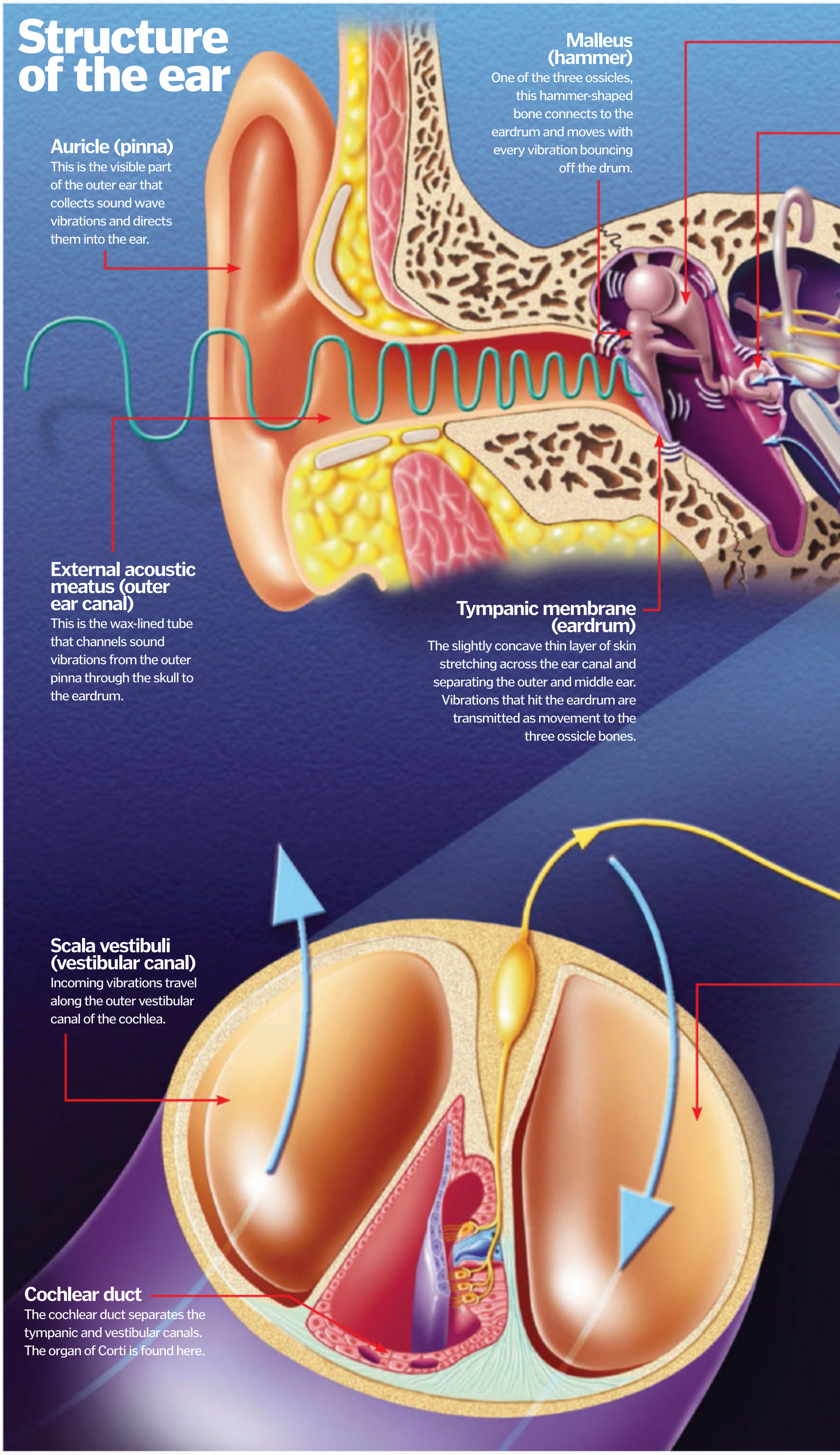
The thing to remember when learning about the human ear is that sound is all about movement. When someone speaks or makes any kind of movement, the air around them is disturbed, creating a sound wave of alternating high and low frequency. These waves are detected by the ear and interpreted by the brain as words, tunes or sounds.

Consisting of air-filled cavities, labyrinthine fluid-filled channels and highly sensitive cells, the ear has external, middle and internal parts. The outer ear consists of a skin-covered flexible cartilage flap called the 'auricle', or 'pinna'. This feature is shaped to gather sound waves and amplify them before they enter the ear for processing and transmission to the brain. The first thing a sound wave entering the ear encounters is the sheet of tightly pulled tissue separating the outer and middle ear. This tissue is the eardrum, or tympanic membrane, and it vibrates as sound waves hit it.

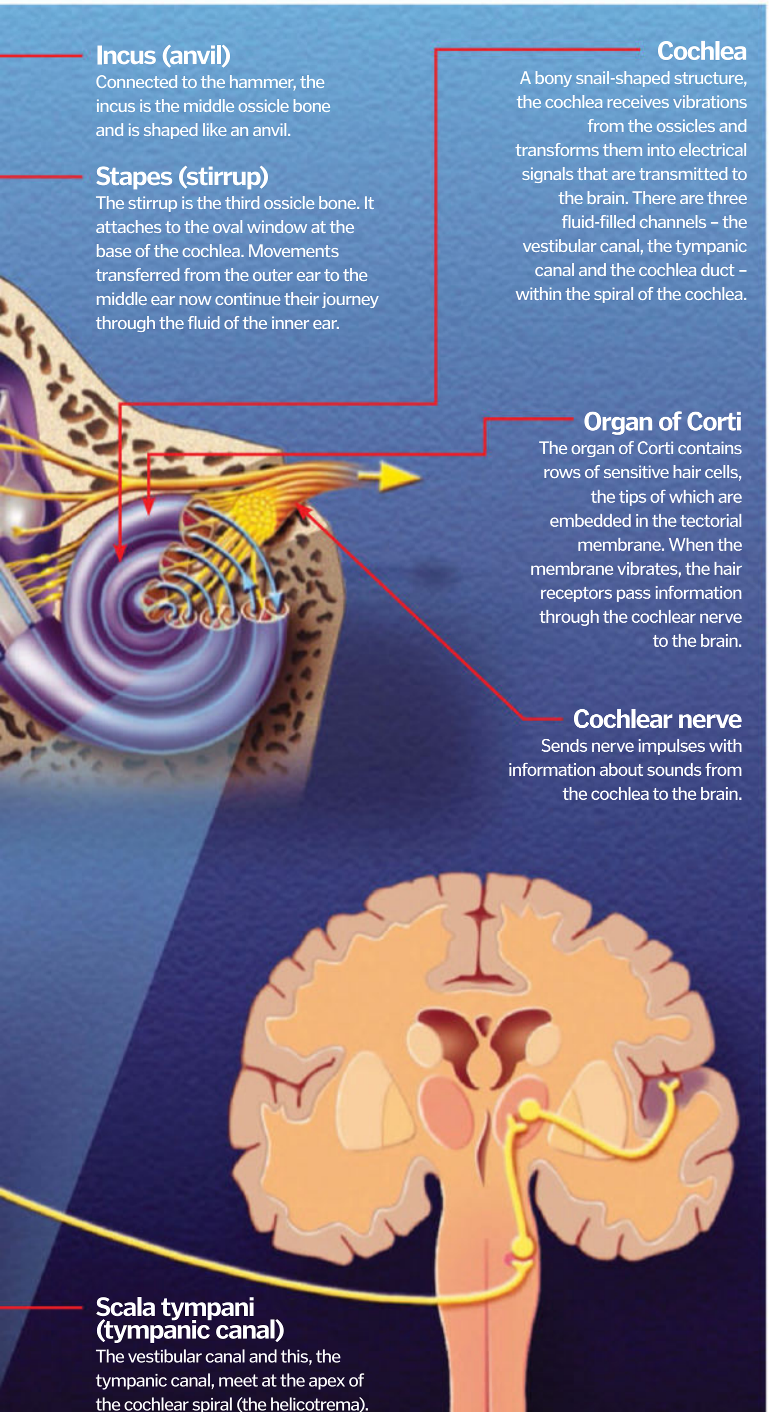
Beyond the eardrum, in the air-filled cavity of the middle ear, are three tiny bones called the 'ossicles'. These are the smallest bones in your body. Sound vibrations hitting the eardrum pass to the first ossicle, the malleus (hammer). Next the waves proceed along the incus (anvil) and then on to the (stapes) stirrup. The stirrup presses against a thin layer of tissue called the 'oval window', and this membrane enables sound waves to enter the fluid-filled inner ear.

The inner ear is home to the cochlea, which consists of watery ducts that channel the vibrations, as ripples, along the cochlea's spiralling tubes. Running through the middle of the cochlea is the organ of Corti, which is lined with minute sensory hair cells that pick up on the vibrations and generate nerve impulses that are sent to the brain as electrical signals. The brain can interpret these signals as sounds.

Structure of the ear



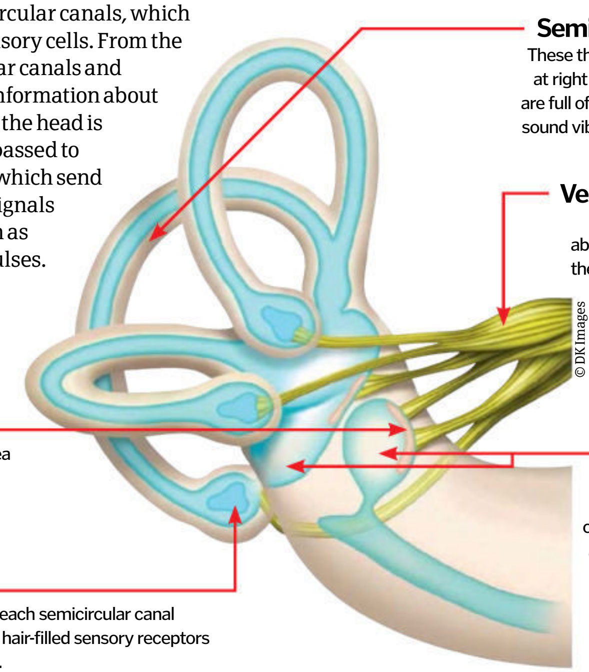
DID YOU KNOW? *The eardrum needs to move less than the diameter of a hydrogen atom in order for us to perceive sound*



Think of sounds as movements, or disturbances of air, that create waves

The vestibular system

Inside the inner ear are the vestibule and semicircular canals, which feature sensory cells. From the semicircular canals and maculae, information about which way the head is moving is passed to receptors, which send electrical signals to the brain as nerve impulses.



A sense of balance

The vestibular system functions to give you a sense of which way your head is pointing in relation to gravity. It enables you to discern whether your head is upright or not, as well as helping you to maintain eye contact with stationary objects while your head is turning.

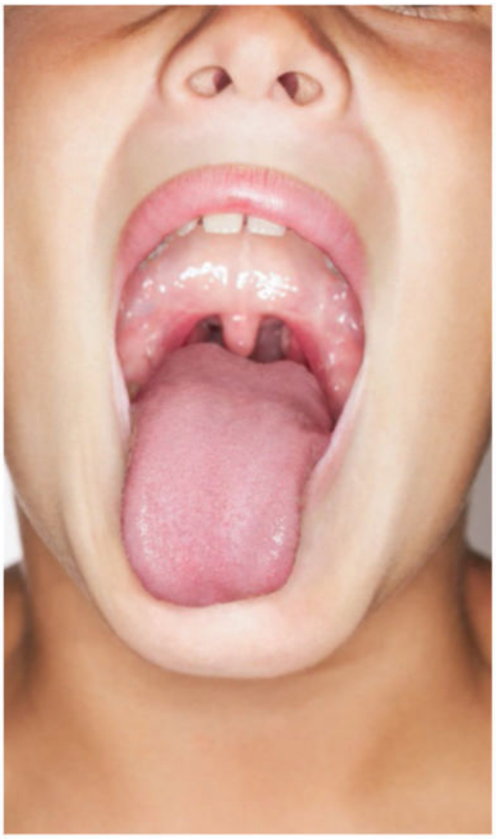
Also located within the inner ear, but less to do with sound and more concerned with the movement of your head, are the semicircular canals. Again filled with fluid, these looping ducts act like internal accelerometers that can detect acceleration (ie, movement of your head) in three different directions due to the positioning of the loops along different planes. Like the organ of Corti, the semicircular canals employ tiny hair cells to sense movement. The canals are connected to the auditory nerve at the back of the brain.

Your sense of balance is so complex that the area of your brain that's dedicated to this one role involves the same number of cells as the rest of your brain cells put together.

The surfer's semicircular canals are as crucial as his feet when it comes to staying on his board

What are tonsils for?

What purpose do these fleshy lumps in the back of our throats serve?



Tonsils are the small masses of flesh found in pairs at the back of the throats of many mammals. In humans the word is actually used to describe three sets of this spongy lymphatic tissue: the lingual tonsils, the pharyngeal tonsils and the more commonly recognised palatine tonsils.

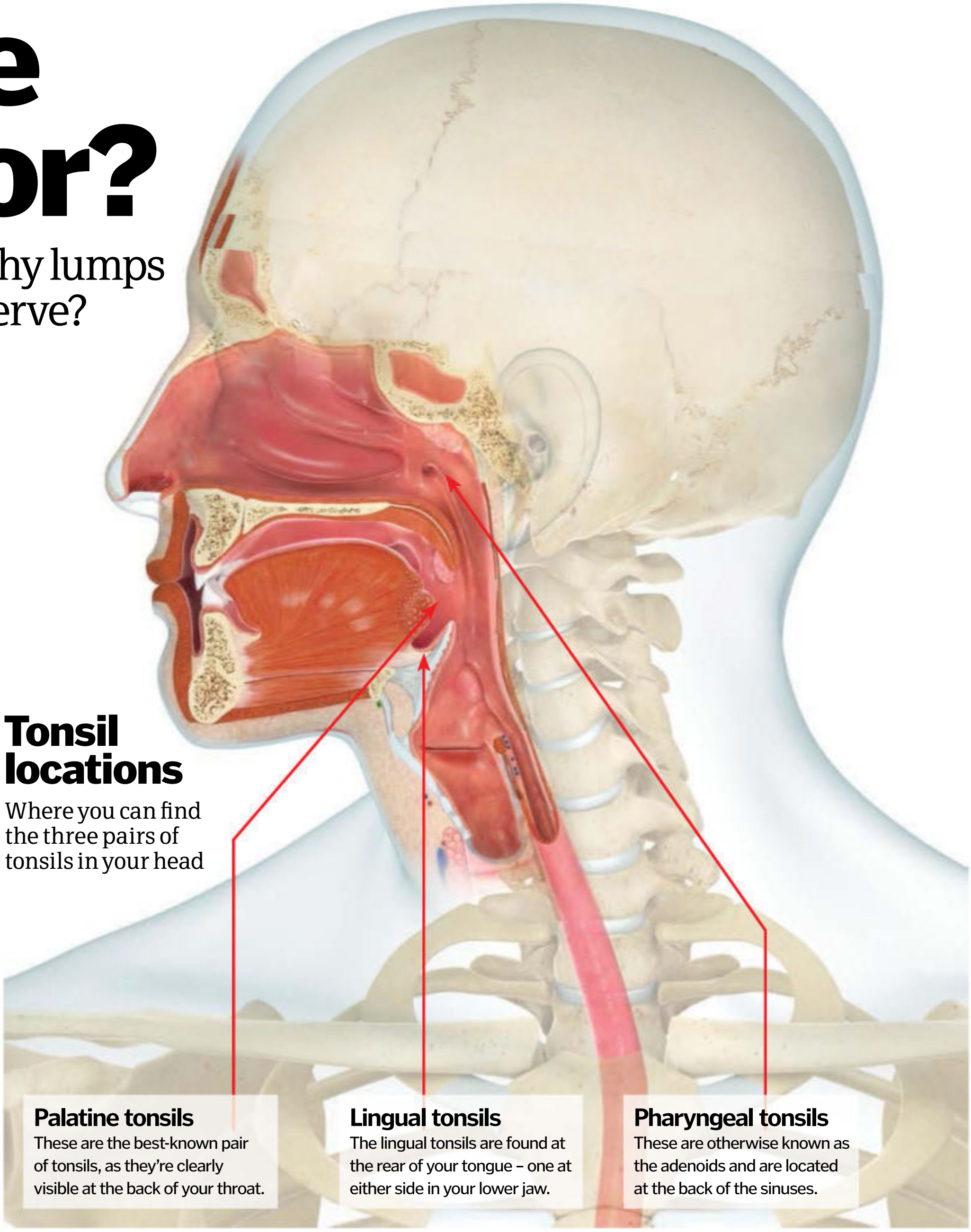
The palatine tonsils are the oval bits that hang down from either side at the back of your throat – you can see them if you look in the mirror. Although the full purpose of the palatine tonsils isn't yet understood, because they produce antibodies and because of their prominent position in the throat, they're thought to be the first line of defence against potential infection in both the respiratory and digestive tracts.

The pharyngeal tonsils are also known as the adenoids. These are found tucked away in the nasal pharynx and serve a similar purpose to the palatine tonsils but shrink in adulthood.

The lingual tonsils are found at the back of the tongue towards the root and, if you poke your tongue right out, you should spot them. These are drained very efficiently by mucous glands so they very rarely get infected.

Tonsil locations

Where you can find the three pairs of tonsils in your head



Palatine tonsils
These are the best-known pair of tonsils, as they're clearly visible at the back of your throat.

Lingual tonsils
The lingual tonsils are found at the rear of your tongue – one at either side in your lower jaw.

Pharyngeal tonsils
These are otherwise known as the adenoids and are located at the back of the sinuses.

Lots of bed rest, fluids and pain relief like paracetamol are all recommended for treating tonsillitis

Tonsillitis in focus

Tonsillitis is caused by certain bacteria (eg group A beta-haemolytic streptococci), and sometimes viral infections, that result in a sore and swollen throat, a fever, white spots at the back of the throat and difficulty swallowing. Usually rest and antibiotics will see it off, but occasionally the infection can cause serious problems or reoccur very frequently. In these cases, a tonsillectomy may be considered,where the tonsils are removed.

The adenoids are less commonly infected but, when they are, they become inflamed, obstruct breathing through the nose and interfere with drainage from the sinuses, which can lead to further infections. In younger people, constant breathing through the mouth can stress the facial bones and cause deformities as they grow, which is why children will sometimes have their adenoid glands removed.

How do humans speak?

The vocal cords and larynx in particular have evolved over time to enable humans to produce a dramatic range of sounds in order to communicate – but how do they work?

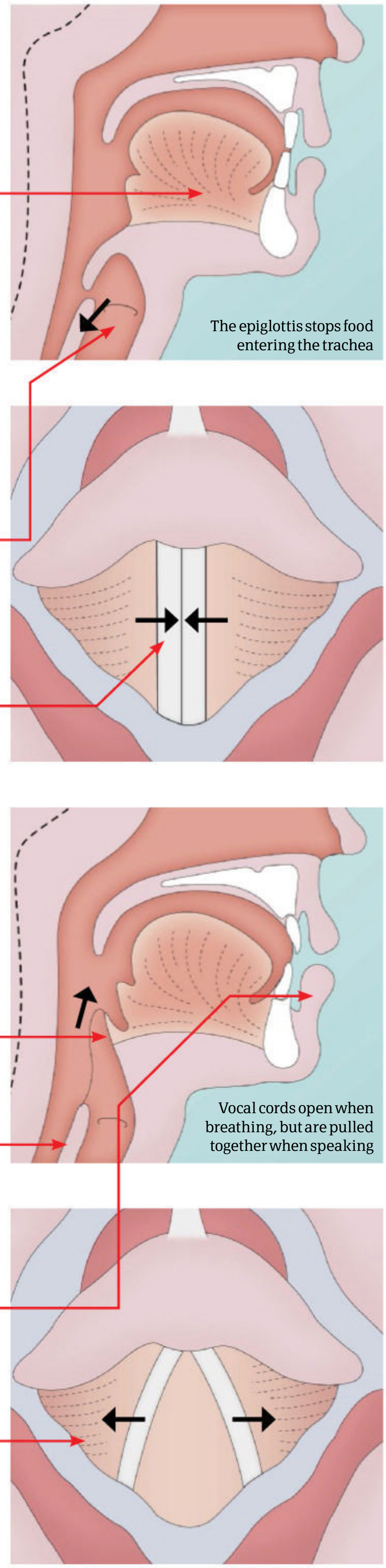
Vocal cords, also known as vocal folds, are situated in the larynx, which is placed at the top of the trachea. They are layers of mucous membranes that stretch across the larynx and control how air is expelled from the lungs in order to make certain sounds. The primary usage of vocal cords within humans is to communicate and it is hypothesised that human vocal cords actually developed to the extent we see now to facilitate advanced levels of communication in response to the formation of social groupings during phases of primate, and specifically human, evolution.

As air is expelled from the lungs, the vocal folds vibrate and collide to produce a range of sounds. The type of sound emitted is effected by exactly how the folds collide, move and stretch as air passes over them. An individual 'fundamental frequency' is determined by the length, size and tension of their vocal cords. Movement of the vocal folds is controlled by the vagus nerve, and sound is then further fine-tuned to form words and sounds that we can recognise by the larynx, tongue and lips. Fundamental frequency in males averages at 125Hz, and at 210Hz in females. Children have a higher average pitch at around 300Hz.

Differences between male and female vocal cords

Male voices are often much lower than female voices. This is primarily due to the different size of vocal folds present in each sex, with males having larger folds that create a lower pitched sound, and females having smaller folds that create a higher pitch sound. The average size for male vocal cords are between 17 and 25mm, and females are normally between 12.5 and 17.5mm. From the range in size, however, males can be seen to have quite high pitch voices, and females can have quite low pitch voices.

The other major biological difference that effects pitch is that males generally have a larger vocal tract, which can further lower the tone of their voice independent of vocal cord size. The pitch and tone of male voices has been studied in relation to sexual success, and individuals with lower voices have been seen to be more successful in reproduction. The reason proposed for this is that a lower tone voice may indicate a higher level of testosterone present in a male.



Tongue
This muscle, situated in the mouth, can affect and change sound as it travels up from the vocal cords and out through the mouth.

Trachea
The vocal cords are situated at the top of the trachea, which is where air from the lungs travels up through from the chest.

Vocal cords
These layers of mucous membranes stretch across the larynx and they open, close and vibrate to produce different sounds.

Epiglottis
This is a flap of skin that shuts off the trachea when an individual is swallowing food. It stops food and liquids 'going down the wrong way'.

Oesophagus
This tube, situated behind the trachea, is where food and liquid travels down to the stomach.

Lips
Lips are essential for the production of specific sounds, like 'b' or 'p'.

Larynx
Known as the voice box, this protects the trachea and is heavily involved in controlling pitch and volume. The vocal cords are situated within the larynx.

The biological structures that are so versatile they enable us to eat a well varied diet

All about teeth

The trouble with teeth

Tooth decay, also often known as dental caries, affects the enamel and dentine of a tooth, breaking down tissue and creating fissures in the enamel. Two types of bacteria – namely Streptococcus mutans and Lactobacillus – are responsible for tooth decay.

Tooth decay occurs after repeated contact with acid-producing bacteria. Environmental factors have a strong effect. Sucrose, fructose and glucose cause problems, and diet is a factor in maintaining good oral health.

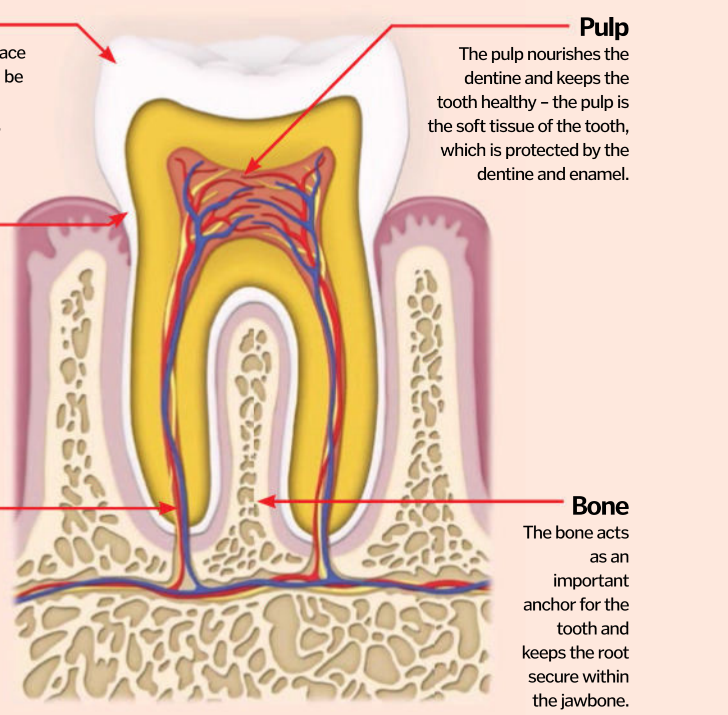
The mouth contains an enormous variety of bacteria, which collects around the teeth and gums. This is visible in the form of a sticky white substance called plaque. Plaque is known as a biofilm. After eating, the bacteria in the mouth metabolises sugar, which subsequently attacks the areas around the teeth.

The primary function of teeth is to crunch and chew food. For this reason, teeth are made of strong substances – namely calcium, phosphorus and various mineral salts. The main structure of the tooth is dentine, which is itself enclosed in a shiny substance called enamel. This strong white coating is the hardest material to be found in the human body.

Humans have different types of teeth that function in various ways. Incisors tear at food, such as the residue found on bones, while bicuspids have long sharp structures that are also used for ripping. Bicuspids tear and crush while molars, which have a flatter surface, grind the food before swallowing. This aids digestion. Because humans have a varied array of teeth (called collective dentition) we are able to eat a complex diet of both meat and vegetables. Other species, such as grazing animals, have specific types of teeth. Cows, for example, have large flat teeth, which restrict them to a simple 'grazing' diet.

Teeth have many functions, in some cases they aid hunting but they also have strong psychological connotations. Both animals and humans bare their teeth when faced with an aggressive situation. Teeth are the most enduring features of the human body. Mammals are described as 'diphyodont', which means they develop two sets of teeth. In humans the teeth first appear at six months old and are replaced by secondary teeth after six or seven years. Some animals develop only one set of teeth, while sharks, for instance, grow a new set of teeth every two weeks.

With humans, tooth loss can occur through accident, gum disease or old age. From ancient times healers have sought to treat and replace the teeth with false ones. Examples of this practice can be seen from ancient Egyptian times and today, we see revolutionary new techniques in the form of dental implants, which are secured deep within the bone of the jaw.



Inside your mouth

The upper and lower areas of the mouth are known as the maxilla and the mandible. The upper area of the mouth is attached to the skull bone and is often called the upper arch of the mouth, while the mandible is the v-shaped bone that carries the lower set of teeth.

Canine teeth

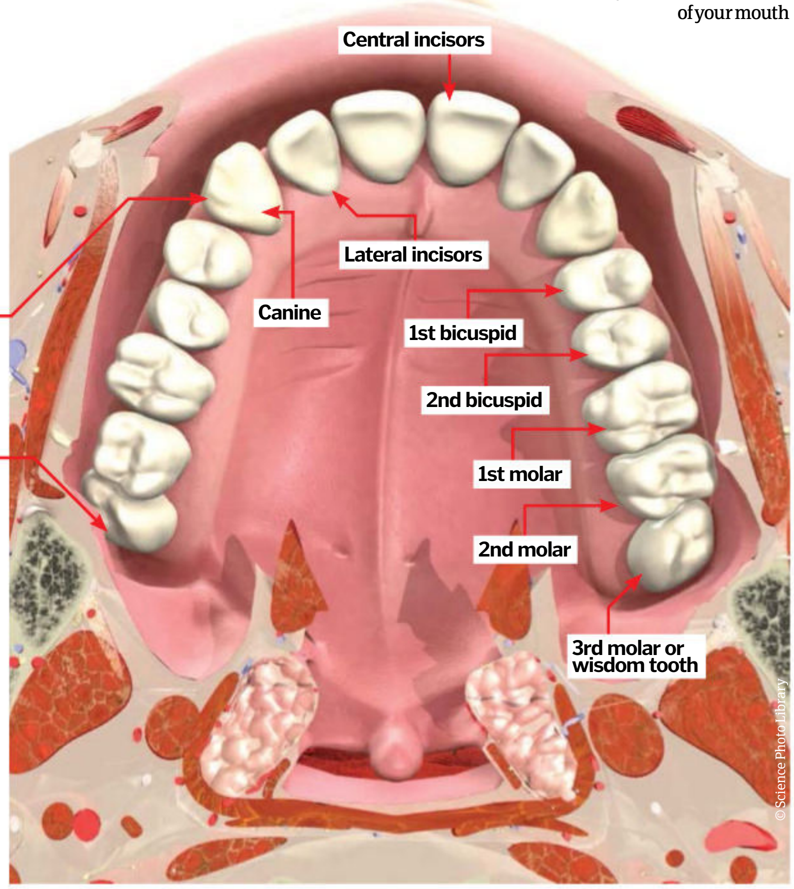
Long, pointed teeth that are used for holding and tearing at the food within the mouth.

Wisdom teeth

Usually appear between the ages of 17 and 25, and often erupt in a group of four.

Maxilla

A layout of the upper area of your mouth

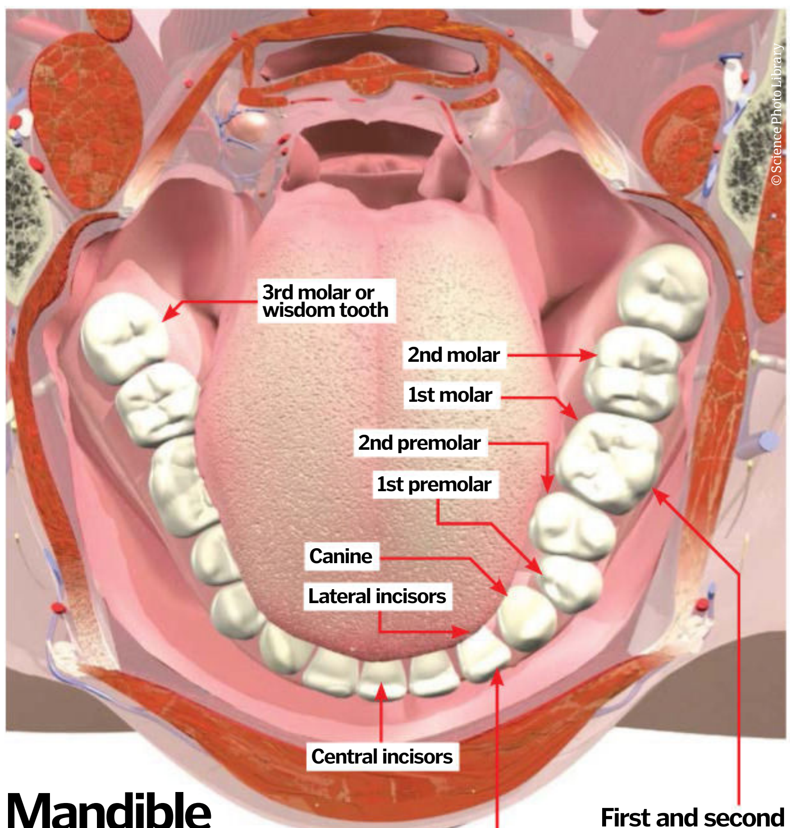


Regular check-ups help keep teeth healthy

Tooth anatomy

The tooth is a complex structure. The enamel at the surface of the tooth is highly visible while the dentine is a hard but porous tissue found under the enamel. The gums provide a secure hold for the tooth, while the root is anchored right into the jawbone. In the centre of the tooth there is a substance called 'pulp' which contains nerves and blood vessels, the pulp nourishes the dentine and keeps the tooth healthy.

Tooth formation begins before birth. Normally there are 20 primary teeth (human baby teeth) and later, 28 to 32 permanent teeth, which includes the wisdom teeth. Of the primary teeth, ten are found in the maxilla (the upper jaw) and ten in the mandible (lower jaw), while the mature adult has 16 permanent teeth in the maxilla and 16 in the mandible.



Mandible

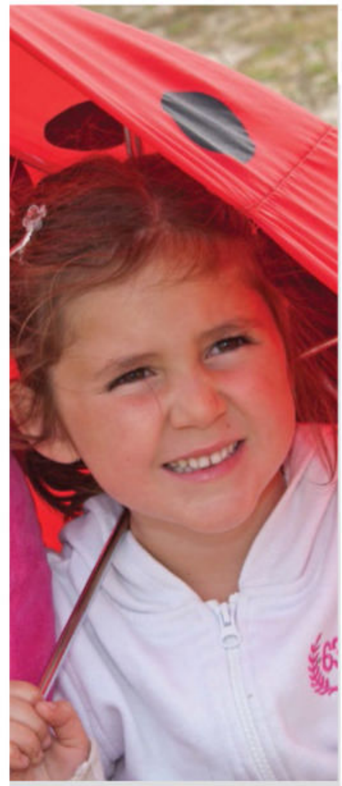
A look inside your lower jawbone

Lateral and central incisors

Incisor comes from the Latin word 'to cut', they are used to grip and bite.

First and second premolar teeth

The premolar or bicuspids are located between the canine and molar teeth. They are used for chewing.



Eruption of teeth

The approximate ages at which the permanent teeth begin to erupt

Age 6
First molar

Age 7
Central incisor

Age 9
First premolar

Age 10
Second premolar

Age 11
Canine

Age 12
Second molar

Age 17 to 21 or not at all
Third molar (wisdom teeth)

Anatomy of the neck

Explore one of the most complex and functional areas of the human body

The human neck is a perfect blend of form and function. It has several specific tasks (eg making it possible to turn our heads to see), while serving as a conduit for other vital activities (eg connecting the mouth to the lungs).

The anatomical design of the neck would impress modern engineers. The flexibility of the cervical spine allows your head to rotate, flex and tilt many thousands of times a day.

The muscles and bones provide the strength and flexibility required, however the really impressive design comes with the trachea, oesophagus, spinal cord, myriad nerves and the vital blood vessels. These structures must all find space and function perfectly at the same time. They must also be able to maintain their shape while the neck moves.

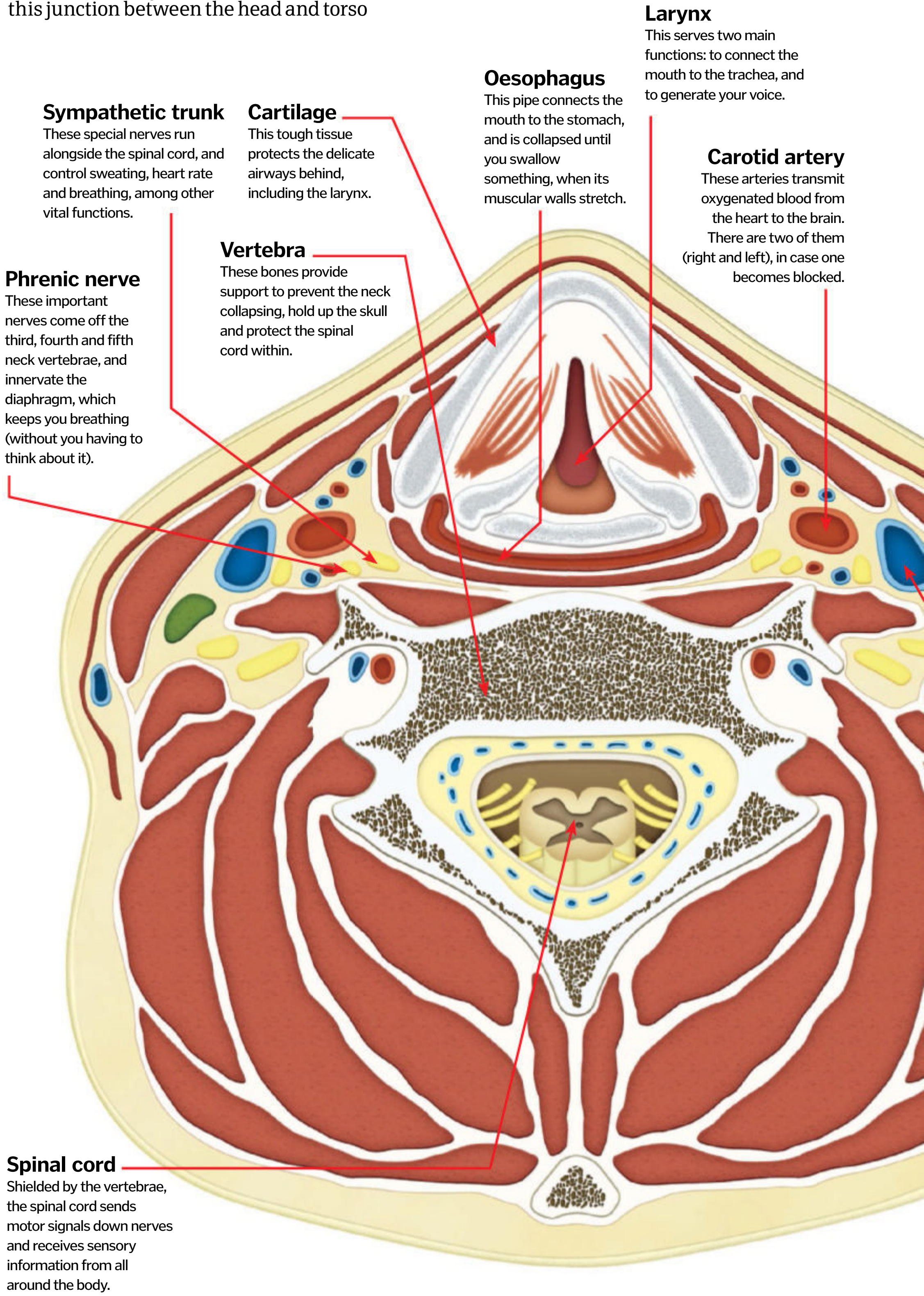
These structures are all highly adapted to achieve their aims. The trachea is protected by a ring of strong cartilage so it doesn't collapse, while allowing enough flexibility to move when stretched. Above this, the larynx lets air move over the vocal cords so we can speak. Farther back, the oesophagus is a muscular tube which food and drink pass through en route to the stomach. Within the supporting bones of the neck sits the spinal cord, which transmits the vital nerves allowing us to move and feel. The carotid arteries and jugular veins, meanwhile, constantly carry blood to and from the brain.

How does the head connect to the neck?

They are connected at the bottom of the skull and at the top of the spinal column. The first vertebra is called the atlas and the second is called the axis. Together these form a special pivot joint that grants far more movement than other vertebrae. The axis contains a bony projection upwards, upon which the atlas rotates, allowing the head to turn. The skull sits on top of slightly flattened areas of the atlas, providing a safe platform for it to stabilise on, and allowing for nodding motions. These bony connections are reinforced with strong muscles, adding further stability. Don't forget that this amazing anatomical design still allows the vital spinal cord to pass out of the brain. The cord sits in the middle of the bony vertebrae, where it is protected from bumps and knocks. It sends out nerves at every level (starting right from the top) granting control over most of the body.

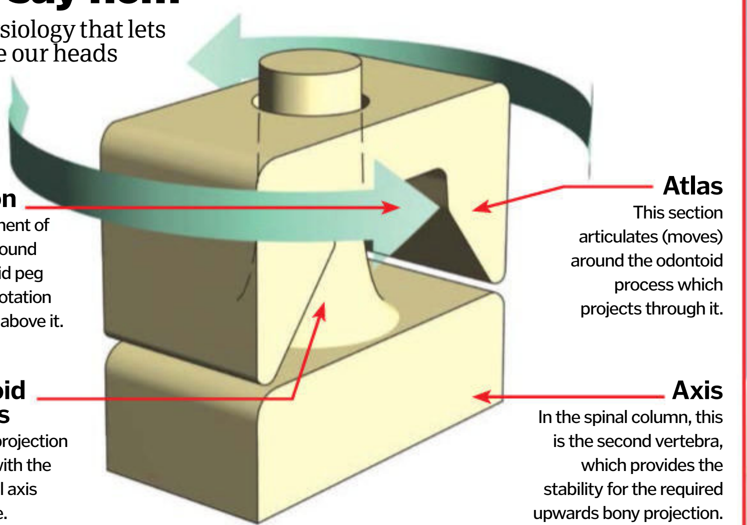
Get it in the neck

We show the major features that are packed into this junction between the head and torso



Just say no…

The physiology that lets us shake our heads



Rotation
The movement of the atlas around the odontoid peg allows for rotation of the skull above it.

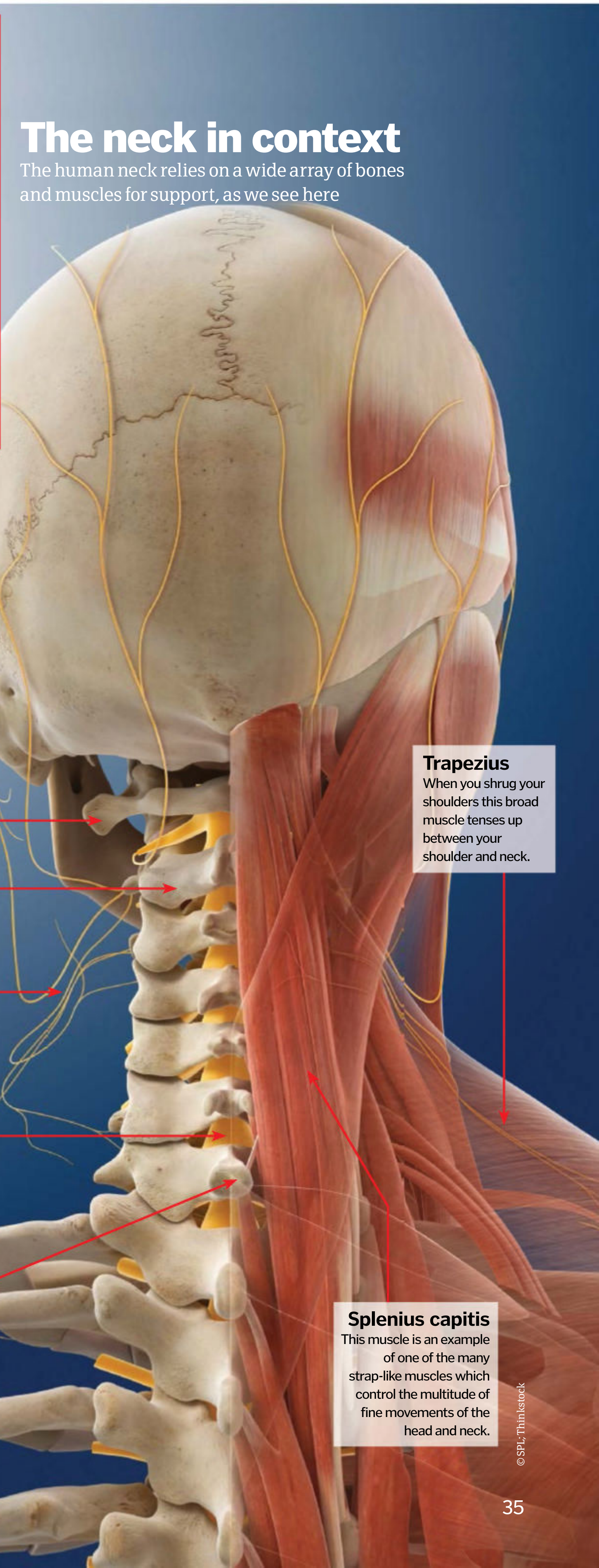
Odontoid process
This bony projection is parallel with the longitudinal axis of the spine.

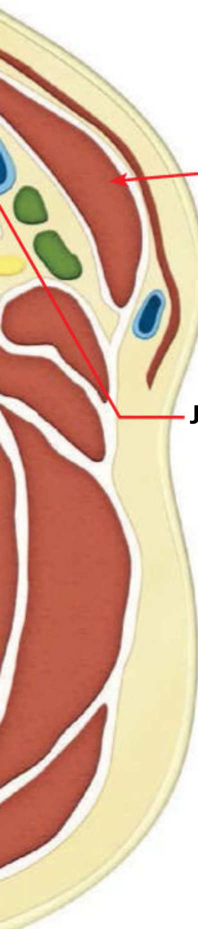
Atlas
This section articulates (moves) around the odontoid process which projects through it.

Axis
In the spinal column, this is the second vertebra, which provides the stability for the required upwards bony projection.

The neck in context

The human neck relies on a wide array of bones and muscles for support, as we see here





Sternocleidomastoid
Turn your head left and feel the right of your neck – this is the muscle doing the turning.

Jugular vein
These vessels drain blood from the neck, returning it to the heart.

Atlas
The first neck (cervical) vertebra is what permits the nodding motion of the head.

Axis
The second cervical vertebra allows rotation of the head. So when you're shaking your head to say no, you have got this bone to thank.

Cervical plexus
These nerves provide sensation to the skin and also control the fine movements of the neck.

Spinal cord
Vertebrae create a cage of bones to protect the critical spinal cord within.

Seventh cervical vertebra
This is the bony protuberance at the bottom of your neck, which you can feel; doctors use it as a kind of landmark so they can locate the other vertebrae.

Trapezius
When you shrug your shoulders this broad muscle tenses up between your shoulder and neck.

Splenius capitis
This muscle is an example of one of the many strap-like muscles which control the multitude of fine movements of the head and neck.

How the human skeleton works

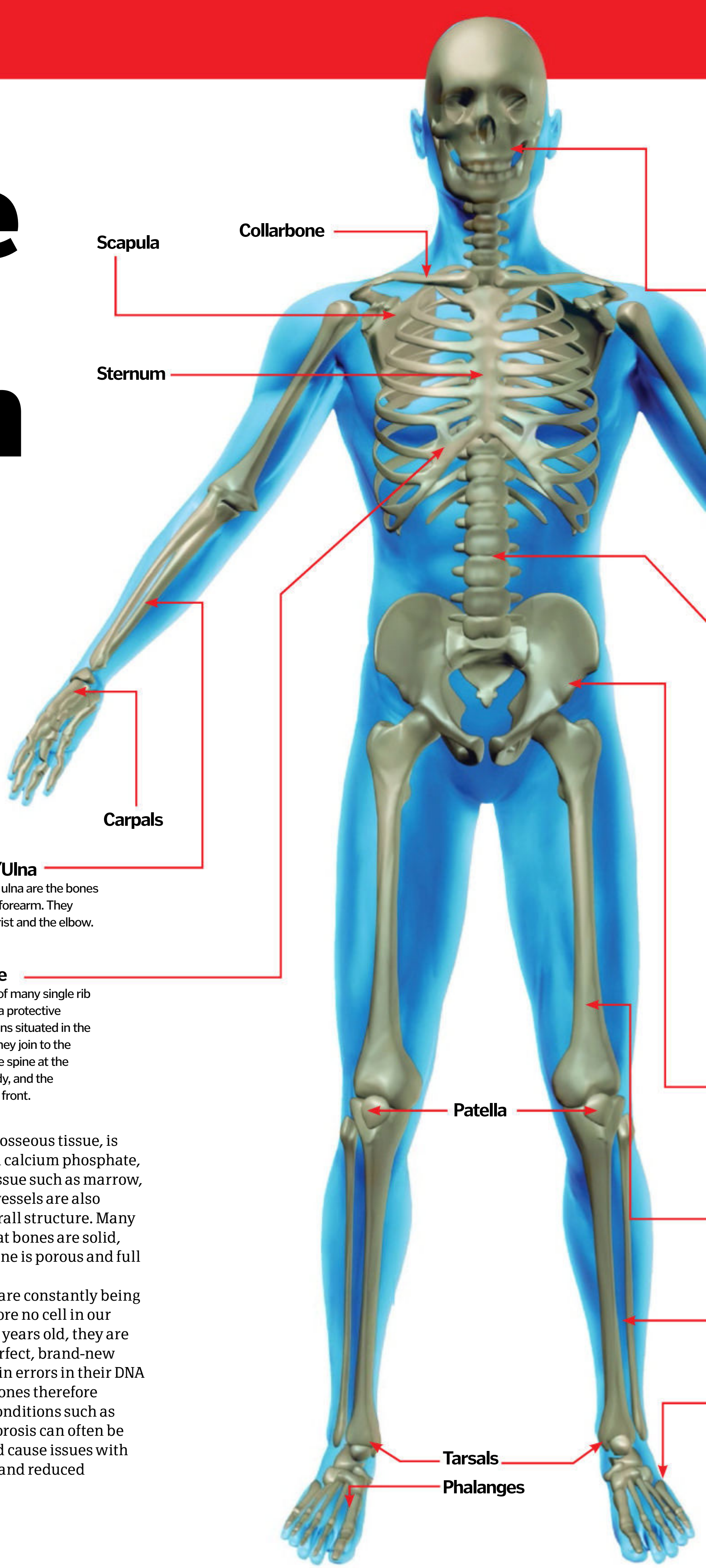
Without a skeleton, we would not be able to live. It is what gives us our shape and structure and its presence allows us to operate on a daily basis. It also is a fascinating evolutionary link to all other living and extinct vertebrates

The human skeleton is crucial for us to live. It keeps our shape and muscle attached to the skeleton allows us the ability to move around, while also protecting crucial organs that we need to survive. Bones also produce blood cells within bone marrow and store minerals we need released on a daily basis.

As an adult you will have around 206 bones, but you are born with over 270, which continue to grow, strengthen and fuse after birth until around 18 in females and 20 in males. Skeletons actually do vary between sexes in structure also. One of the most obvious areas is the pelvis as a female must be able to give birth, and therefore hips are comparatively shallower and wider. The cranium also becomes more robust in males due to heavy muscle attachment and a male's chin is often more prominent. Female skeletons are generally more delicate overall. However, although there are several methods, sexing can be difficult because of the level of variation we see within the species.

Bones are made up of various different elements. In utero, the skeleton takes shape as cartilage, which then starts to calcify and develop during gestation and following birth. The primary element that makes up bone, osseous tissue, is actually mineralised calcium phosphate, but other forms of tissue such as marrow, cartilage and blood vessels are also contained in the overall structure. Many individuals think that bones are solid, but actually inner bone is porous and full of little holes.

Even though cells are constantly being replaced, and therefore no cell in our body is more than 20 years old, they are not replaced with perfect, brand-new cells. The cells contain errors in their DNA and ultimately our bones therefore weaken as we age. Conditions such as arthritis and osteoporosis can often be caused by ageing and cause issues with weakening of bones and reduced movement ability.

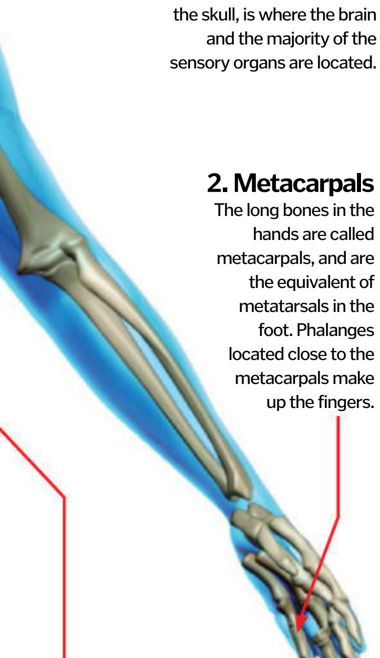


4. Radius/Ulna
The radius and ulna are the bones situated in the forearm. They connect the wrist and the elbow.

5. Rib cage
This structure of many single rib bones creates a protective barrier for organs situated in the chest cavity. They join to the vertebrae in the spine at the back of the body, and the sternum at the front.

Inside our skeleton

How the human skeleton works and keeps us upright



1. Cranium
The cranium, also known as the skull, is where the brain and the majority of the sensory organs are located.

2. Metacarpals
The long bones in the hands are called metacarpals, and are the equivalent of metatarsals in the foot. Phalanges located close to the metacarpals make up the fingers.

3. Vertebrae
There are three main kinds of vertebrae (excluding the sacrum and coccyx) – cervical, thoracic and lumbar. These vary in strength and structure as they carry different pressure within the spine.

6. Pelvis
This is the transitional joint between the trunk of the body and the legs. It is one of the key areas in which we can see the skeletal differences between the sexes.

7. Femur
This is the largest and longest single bone in the body. It connects to the pelvis with a ball and socket joint.

8. Fibula/Tibia
These two bones form the lower leg bone and connect to the knee joint and the foot.

9. Metatarsals
These are the five long bones in the foot that aid balance and movement. Phalanges located close to the metatarsals are the bones which are present in toes.

Breaking bones

Whether it's a complete break or just a fracture, both can take time to heal properly

If you simply fracture the bone, you may just need to keep it straight and keep pressure off it until it heals. However, if you break it into more than one piece, you may need metal pins inserted into the bone to realign it or plates to cover the break in order for it to heal properly. The bone heals by producing new cells and tiny blood vessels where the fracture or break has occurred and these then rejoin up. For most breaks or fractures, a cast external to the body will be put on around the bone to take pressure off the bone to ensure that no more damage is done and the break can heal.

"The skull is actually seven separate plates when we are born, which fuse together"

Skull development

When we are born, many of our bones are still somewhat soft and are not yet fused – this process occurs later during our childhood

The primary reasons for the cranium in particular not to be fully fused at birth is to allow the skull to flex as the baby is born and also to allow the extreme rate of growth that occurs in the first few years of childhood following birth. The skull is actually in seven separate plates when we are born and over the first two years these pieces fuse together slowly and ossify. The plates start suturing together early on, but the anterior fontanel – commonly known as the soft spot – will take around 18 months to fully heal. Some other bones, such as the five bones located in the sacrum, don't fully fuse until late teens or early twenties, but the cranium becomes fully fused by around age two.

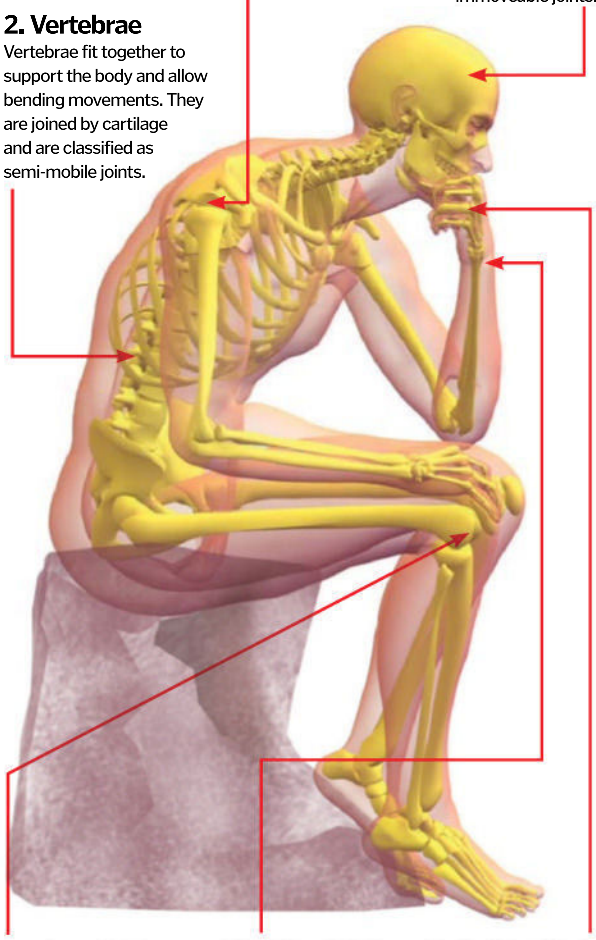
How our joints work

The types of joints in our body explained

1. Ball and socket joints
Both the hip and the shoulder joints are ball and socket joints. The femur and humerus have ball shaped endings, which turn in a cavity to allow movement.

2. Vertebrae
Vertebrae fit together to support the body and allow bending movements. They are joined by cartilage and are classified as semi-mobile joints.

3. Skull sutures
Although not generally thought of as a 'joint', all the cranial sutures present from where bones have fused in childhood are in fact immoveable joints.



4. Hinged joints
Both elbows and knees are hinged joints. These joints only allow limited movement in one direction. The bones fit together and are moved by muscles.

5. Gliding joints
Some movement can be allowed when flat bones 'glide' across each other. The wrist bones – the carpals – operate like this, moved by ligaments.

6. Saddle joints
The only place we see this joint in humans is the thumb. Movement is limited in rotation, but the thumb can move back, forward and to the sides.

3 skulls © DK Images

The human spine

The human spine is made up of 33 vertebrae, but how do they support our bodies while allowing us such flexibility?

The human spine is made up of 33 vertebrae, 24 of which are articulated (flexible) and nine of which normally become fused in maturity. They are situated between the base of the skull to the pelvis, where the spine trails off into the coccyx – an evolutionary remnant of a tail our ancestors would have displayed.

The primary functions of the vertebrae that make up the spine are to support the torso and head, which protect vital nerves and the spinal cord and allow the individual to move. By sitting closely together, separated only by thin intervertebral discs which work as ligaments and effectively form joints between the bones, the vertebrae form a strong pillar structure which holds the head up and allows for the body to remain upright. It also produces a base for ribs to attach to and to protect vital internal organs in the human body.

Vertebrae are not all fused together because of the need to move, and the vertebrae themselves are grouped into five types – cervical, thoracic, lumbar, sacral and coccygeal. The sacral vertebrae fuse during maturity (childhood and teenage years) and become solid bones towards the base of the spine. The coccygeal vertebrae will fuse in some cases, but studies have shown that often they actually remain separate. Collectively they are referred to as the coccyx (tail bone). The rest of the vertebrae remain individual and discs between them allow them to move in various directions without wearing the bones down. The cervical vertebrae in the neck allow particularly extensive movement, allowing the head to move up and down and side to side. The thoracic are far more static, with ties to the rib cage resisting much movement. The lumbar vertebrae allow modest side-to-side movement and rotation. A particular feature of the spine is how it is actually curved to allow distribution of the body's weight, to ensure no one vertebrae takes the full impact.

C1 (atlas)
This is the vertebrae which connects the spinal column with the skull. It is named 'atlas' after the legend of Atlas who held the entire world on his shoulders.

Cervical vertebrae
These are the smallest of the articulating vertebrae, and support the head and neck. There are seven vertebrae, with C1, C2 and C7's structures quite unique from the others. They sit between the skull and thoracic vertebrae.

C2 (axis)
C2 is the pivot for C1 (atlas), and nearly all movement for shaking your head will occur at this joint – the atlanto-axial joint.

Thoracic vertebrae
The thoracic vertebrae are the intermediately sized vertebrae. They increase in size as you move down the spine, and they supply facets for ribs to attach to – this is how they are primarily distinguished.

Intervertebral discs
These discs form a joint between each vertebrae and, effectively, work as ligaments while also serving as fantastic shock absorbers. They facilitate movement and stop the bones rubbing together.

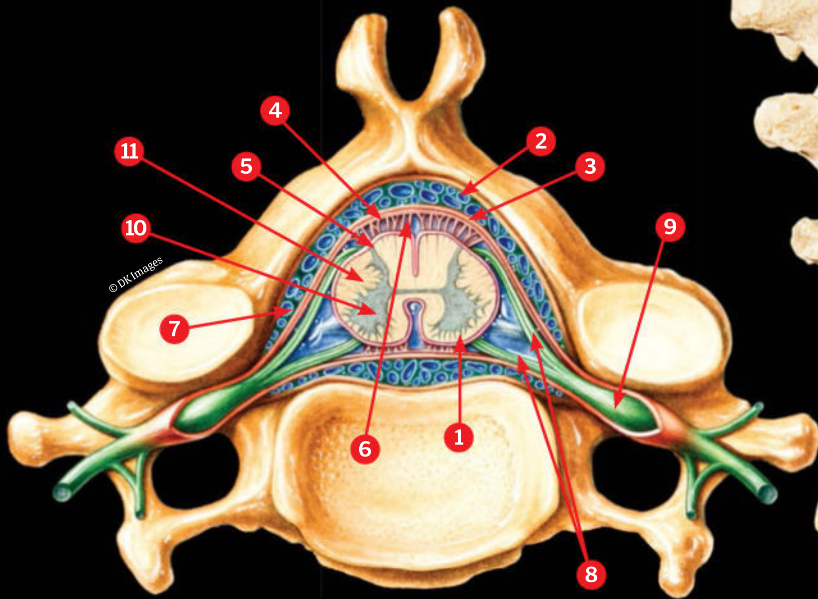
Spine curvature

As you look at the human spine, you can see some distinct curves. The primary reasons for these are to help distribute weight throughout the spine and support aspects of the body. The curve most familiar to us is the lumbar curve, between the ribs and pelvis. This develops when we start to walk at about 12-18 months and helps with weight distribution during locomotion. Prior to this we develop the cervical curve, which allows us to support the weight of our head at around three-four months, and two smaller less-obvious curves in the spine (the thoracic and pelvic curves) are developed during gestation.

Spinal cords and nerves

The human spinal cord is an immensely complex structure made up of nerve cells and a large amount of supporting, protective tissue. It splits into 31 different sections and stretches 43-45cm, down from the brain to between the first and second lumbar vertebrae. Although more commonly referred to in respect of the brain, there is both white and grey matter present in the centre of the spinal cord. White matter contains axons tracts surrounded by fats, and blood vessels to protect them. The grey matter contains more of the neural cell bodies, such as dendrites, more axons and glial cells.

Spinal cord injuries are normally caused by trauma. If the trauma causes intervertebral discs and vertebrae to break, they can pierce the spinal cord, which can result in loss of feeling. Cord severance may result in paralysis.



Spinal column cross-section

1. Spinal cord
This is an immensely important pathway for information to transfer between the brain and the body's nervous system. It is heavily protected by tissue and vertebrae, as any damage to it can be fatal.

2. Epidural space
This is the space between the outer protective tissue layer, dura mater and the bone. It is filled with adipose tissue (fat), while also playing host to numerous blood vessels.

3. Dura mater
This is the tough outer layer of tissue that protects the spinal cord. The three layers of protection between the vertebrae and the spinal cord are called the spinal meninges.

4. Arachnoid mater
Named for its spider web appearance, this is the second layer of the tissue protection provided for the spinal cord.

5. Pia mater
This thin, delicate layer sits immediately next to the spinal cord.

6. Subarachnoid space
This is the space between the pia mater and the arachnoid mater, which is filled with cerebrospinal fluid.

7. Blood vessels
Four arteries, which form a network called the Circle of Willis, deliver oxygen-rich blood to the brain. The brain's capillaries form a lining called the 'blood-brain barrier', which controls blood flow to the brain.

8. Dorsal and ventral roots
These connect the spinal nerves to the spinal cord, allowing transition of information between the brain and the body.

9. Spinal nerves
Humans have 31 pairs of spinal nerves all aligned with individual vertebrae, and these communicate information from around the body to the spinal cord. They carry all types of information – motor, sensory and so on – and are commonly referred to as 'mixed spinal nerves'.

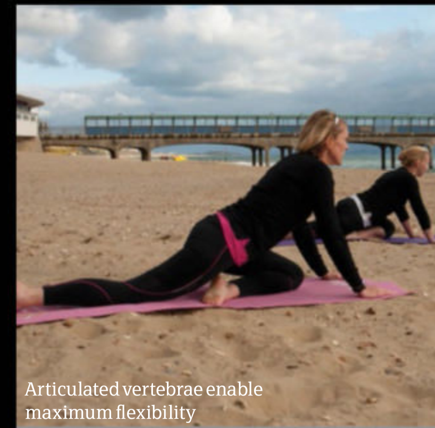
10. Grey matter
Within the horn-like shapes in the centre of the spinal cord, sit most of the important neural cell bodies. They are protected in many ways, including by the white matter.

11. White matter
This area that surrounds the grey matter holds axon trails, but is primarily made up of lipid tissue (fats) and blood vessels.

Lumbar vertebrae
Lumbar vertebrae are the largest of the vertebrae and the strongest, primarily because they withstand the largest pressures. Compared with other vertebrae they are more compact, lacking facets on the sides of the vertebrae.

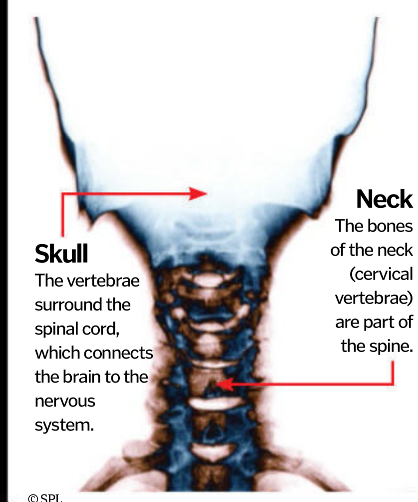
Sacral vertebrae
We have five sacral vertebrae at birth, but by maturity they will have fused to form a solid bone, which helps support the lumbar vertebrae and connect the coccyx to the spine.

Coccyx (tailbone)
The coccyx can display between three and five vertebrae. They're commonly thought to be fused, but often are not. Although these vertebrae are a vestigial remnant of a tail, they have several uses, such as supporting weight when sitting.


Articulated vertebrae enable maximum flexibility

How is the skull attached to the spine?

The skull is connected to the spine by the atlanto-occipital joint, which is created by C1 (atlas) and the occipital bone situated at the base of the cranium (skull). This unique vertebra has no 'body' and actually looks more like a ring than any other vertebra. It sits at the top of the cervical vertebrae and connects with the occipital bone via an ellipsoidal joint, allowing movement such as nodding or rotation of the head. An ellipsoidal joint is where an ovoid connection (in this case the occipital bone) is placed into an elliptical cavity (C1 vertebrae). The rest of the cervical vertebrae also work to support the weight of the head.



Skull
The vertebrae surround the spinal cord, which connects the brain to the nervous system.

Neck
The bones of the neck (cervical vertebrae) are part of the spine.

Joints

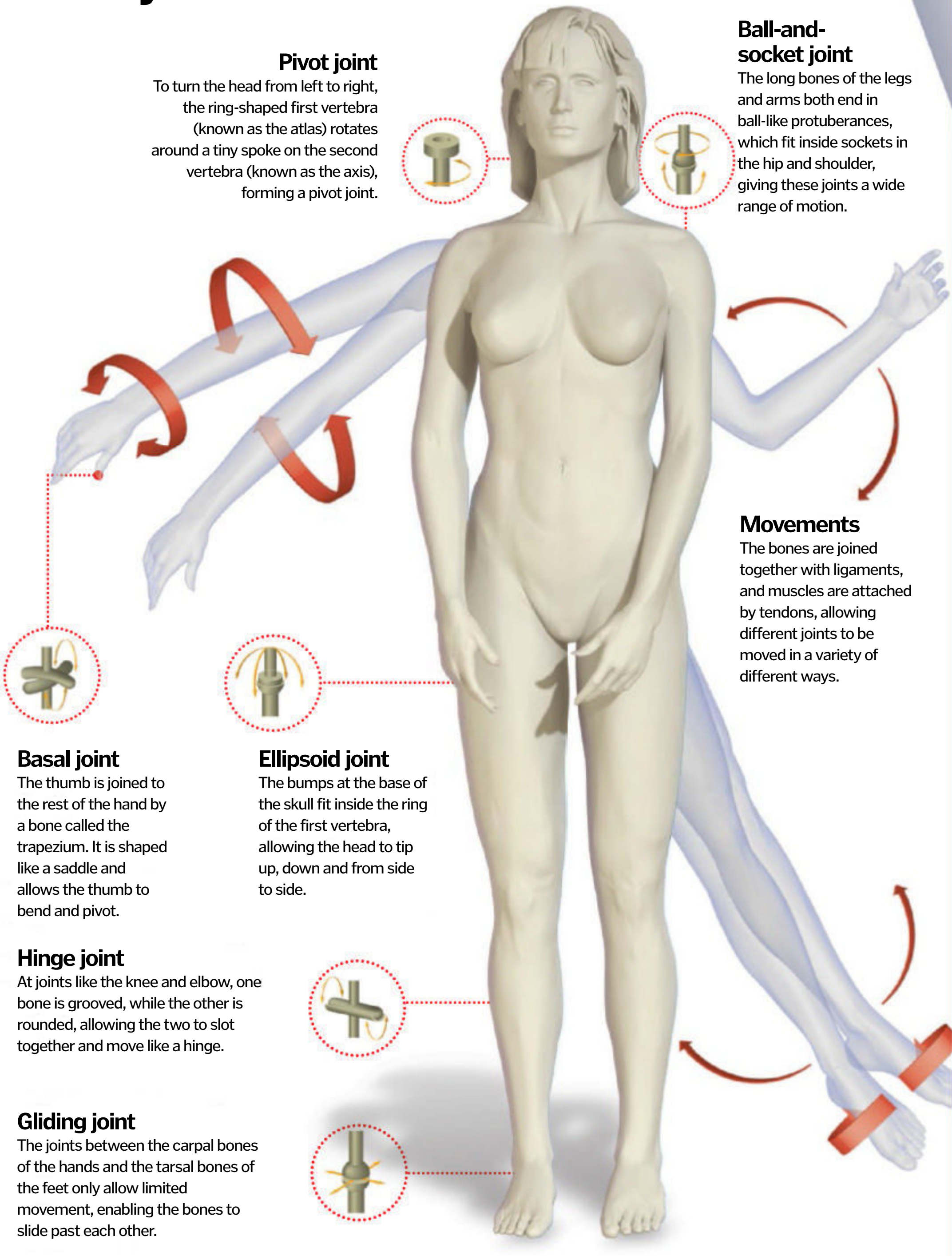
For individual bones to function together, they must be linked by joints

Some bones, like those in the skull, do not need to move, and are permanently fused together with mineral sutures. These fixed joints provide maximum stability. However, most bones need flexible linkages. In some parts of the skeleton, partial flexibility is sufficient, so all that the bones require is a little cushioning to prevent rubbing. The bones are joined by a rigid, gel-like tissue known as cartilage, which allows for a small range of compression and stretching. These types of joints are present where the ribs meet the sternum, providing flexibility when breathing, and between the stacked vertebrae of the spinal column, allowing it to bend and flex without crushing the spinal cord.

Most joints require a larger range of movement. Covering the ends of the bones in cartilage provides shock absorption, but for them to move freely in a socket, the cartilage must be lubricated to make it slippery and wear-proof. At synovial joints, the ends of the two bones are encased in a capsule, covered on the inside by a synovial membrane, which fills the joint with synovial fluid, allowing the bones to slide smoothly past one another.

There are different types of synovial joint, each with a different range of motion. Ball-and-socket joints are used at the shoulder and hip, and provide a wide range of motion, allowing the curved surface at the top end of each limb to slide inside a cartilage covered cup. The knees and elbows have hinge joints, which interlock in one plane, allowing the joint to open and close. For areas that need to be flexible, but do not need to move freely, such as the feet and the palm of the hand, gliding joints allow the bones to slide small distances without rubbing.

Bone joints



Pivot joint
To turn the head from left to right, the ring-shaped first vertebra (known as the atlas) rotates around a tiny spoke on the second vertebra (known as the axis), forming a pivot joint.

Ball-and-socket joint
The long bones of the legs and arms both end in ball-like protuberances, which fit inside sockets in the hip and shoulder, giving these joints a wide range of motion.

Movements
The bones are joined together with ligaments, and muscles are attached by tendons, allowing different joints to be moved in a variety of different ways.

Basal joint
The thumb is joined to the rest of the hand by a bone called the trapezium. It is shaped like a saddle and allows the thumb to bend and pivot.

Ellipsoid joint
The bumps at the base of the skull fit inside the ring of the first vertebra, allowing the head to tip up, down and from side to side.

Hinge joint
At joints like the knee and elbow, one bone is grooved, while the other is rounded, allowing the two to slot together and move like a hinge.

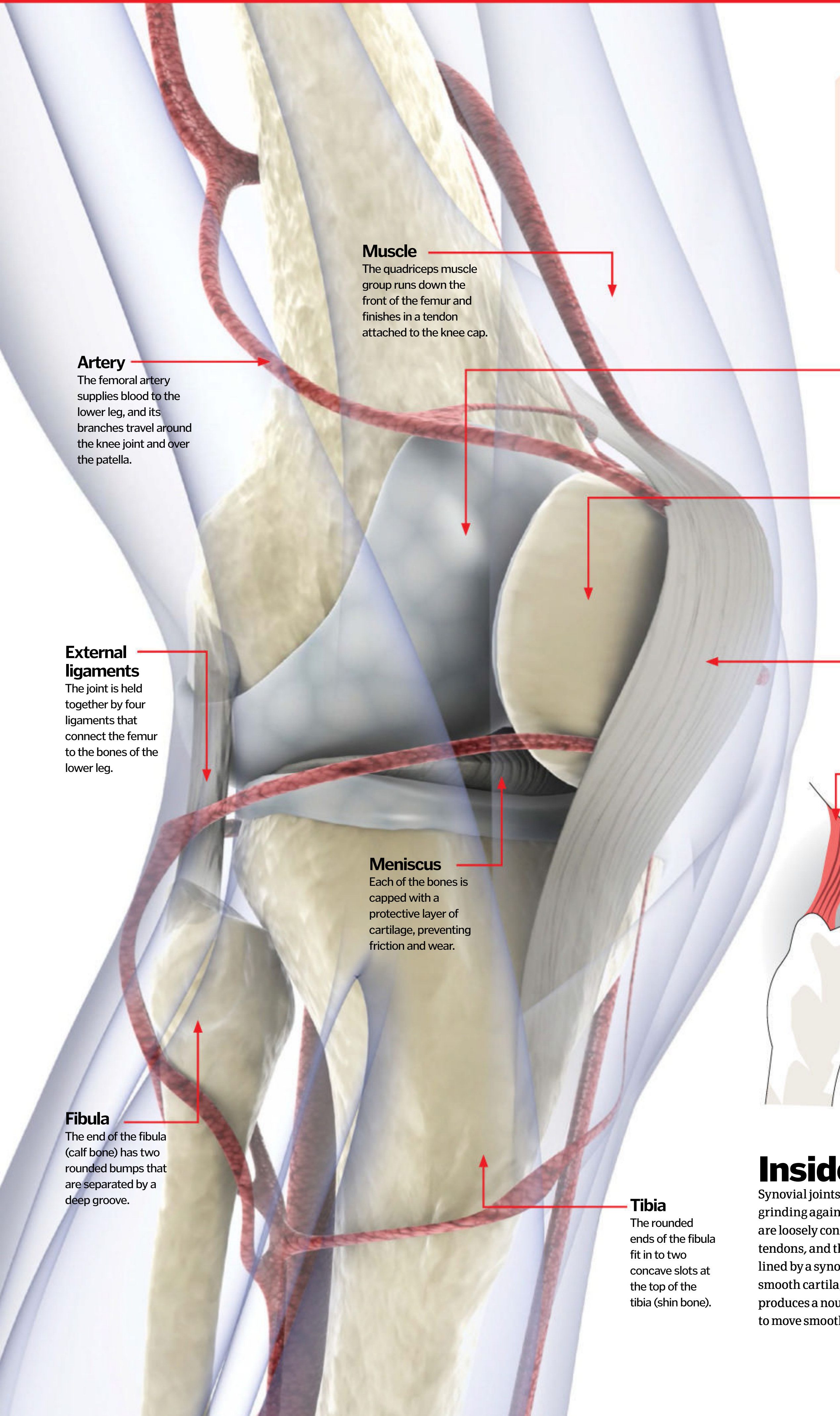
Gliding joint
The joints between the carpal bones of the hands and the tarsal bones of the feet only allow limited movement, enabling the bones to slide past each other.

Hypermobility
Some people have particularly flexible joints and a much larger range of motion. This is sometimes known as being 'double jointed.' It is thought to result from the structure of the collagen in the joints, the shape of the end of the bones, and the tone of the muscles around the joint.

Mobile
The synovial joints are the most mobile in the body. The ends of the bones are linked by a capsule that contains a fluid lubricant, allowing the bones to slide past one another. Synovial joints come in different types, including ball-and-socket, hinge, and gliding.

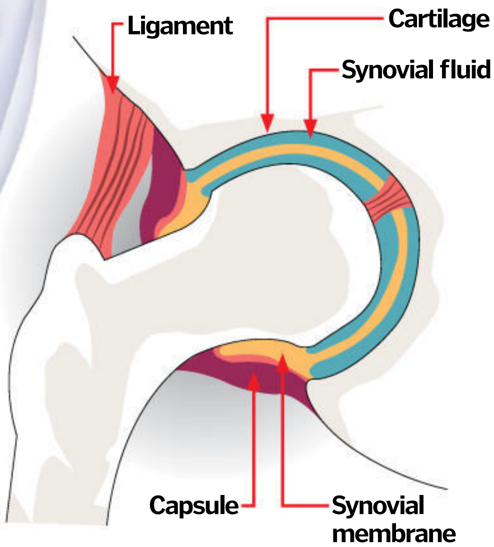
Semi-mobile
Cartilaginous joints do not allow free motion, but cushion smaller movements. Instead of a lubricated capsule, the bones are joined by fibrous or hyaline cartilage. The linkage acts as a shock absorber, so the bones can move apart and together over small distances.

Fixed
Some bones do not need to move relative to one another and are permanently fused. For example the cranium starts out as separate pieces, allowing the foetal head to change shape to fit through the birth canal, but fuses after birth to encase the brain in a solid protective skull.



Why our joints crack

The synovial fluid used to lubricate the joints contains dissolved gasses. The fluid is sealed within a capsule, so if the joint is stretched, the capsule also stretches, creating a vacuum as the pressure changes, and pulling the gas out of solution and into a bubble, which pops, producing a cracking sound.



Inside a joint

Synovial joints prevent mobile areas of the skeleton from grinding against one another as they move. The two bones are loosely connected by strips of connective tissue called tendons, and the two ends are encased in a capsule that is lined by a synovial membrane. The bones are covered in smooth cartilage to prevent abrasion and the membrane produces a nourishing lubricant to ensure the joint is able to move smoothly.

How do muscles work?

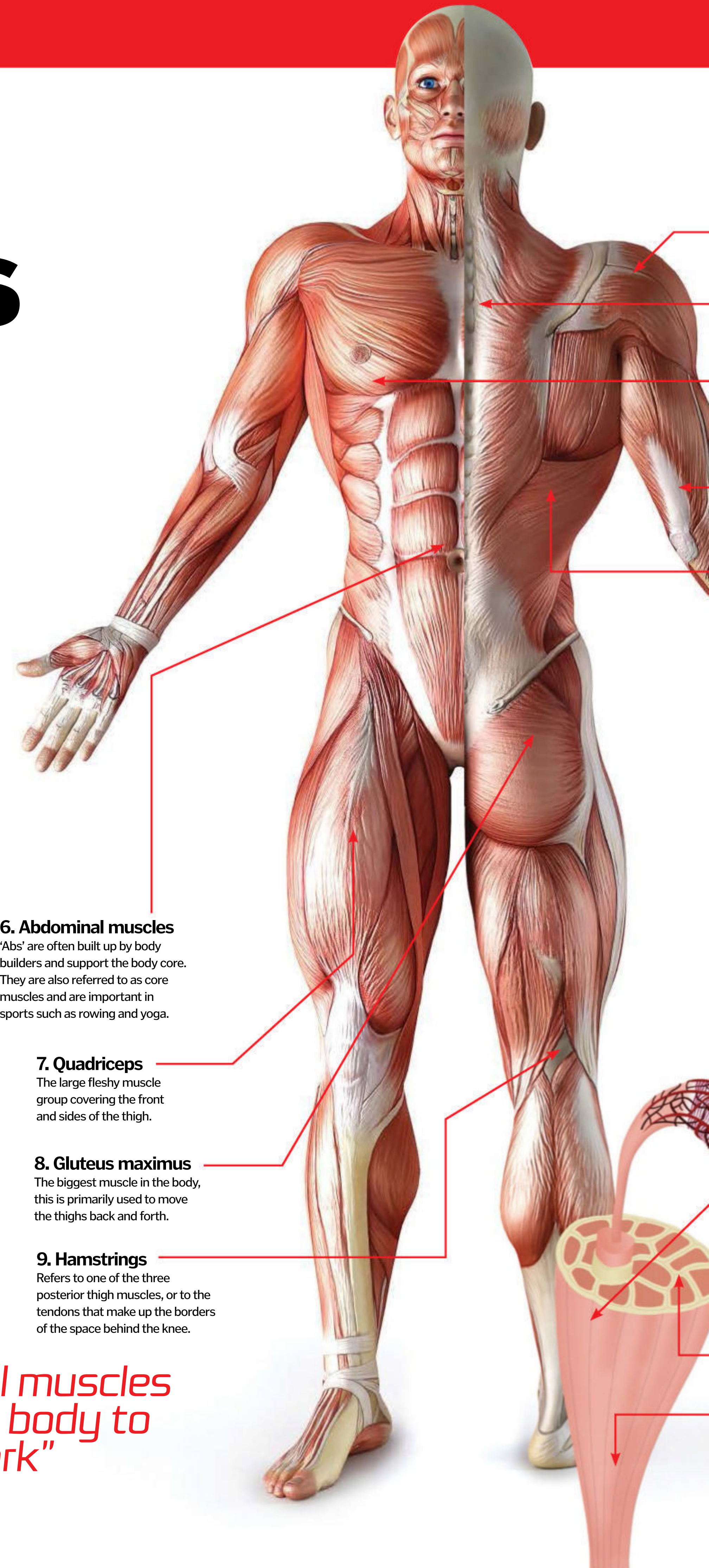
Muscles are essential for us to operate on a daily basis, but how are they structured and how do they keep us moving

A muscle is a group of tissue fibres that contract and release to control movements within the body. We have three different types of muscles in our bodies – smooth muscle, cardiac muscle and skeletal muscle.

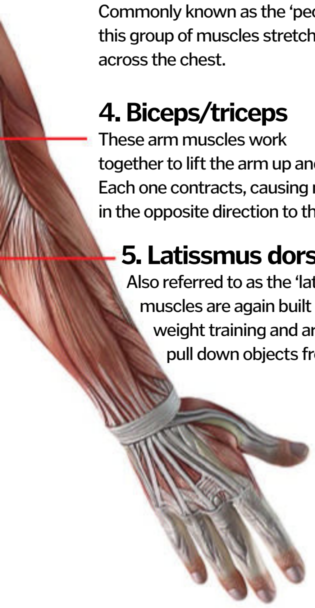
Skeletal muscle, also known as striated muscle, is what we would commonly perceive as muscle, this being external muscles that are attached to the skeleton, such as biceps and deltoids. These muscles are connected to the skeleton with tendons. Cardiac muscle concerns the heart, which is crucial as it pumps blood around the body, supplying oxygen and ultimately energy to muscles, which allows them to operate. Smooth muscle, which is normally sheet muscle, is primarily involved in muscle contractions such as bladder control and oesophagus movements. These are often referred to as involuntary as we have little or no control over these muscles' actions.

Muscles control most functions within our bodies; release of waste products, breathing, seeing, eating and movement to name but a few. Actual muscle structure is quite complex, and each muscle is made up of numerous fibres which work together to give the muscle strength. Muscles increase in effectiveness and strength through exercise and growth and the main way this occurs is through small damage caused by each repetition of a muscle movement, which the body then repairs and improves.

More than 640 muscles are actually present across your entire body to enable your limbs to work, control bodily functions and shape the body as a whole.



"More than 300 individual muscles are present across your body to enable your limbs to work"



1. Deltoids
These muscles stretch across the shoulders and aid lifting.

2. Trapezius
Large, superficial muscle at the back of the neck and the upper part of the thorax, or chest.

3. Pectoralis major
Commonly known as the 'pecs', this group of muscles stretch across the chest.

4. Biceps/triceps
These arm muscles work together to lift the arm up and down. Each one contracts, causing movement in the opposite direction to the other.

5. Latissmus dorsi
Also referred to as the 'lats', these muscles are again built up during weight training and are used to pull down objects from above.

What affects our muscle strength?

How strong we are is a combination of nature and nurture

Muscle strength refers to the amount of force that a muscle can produce, while operating at maximum capacity, in one contraction. Size and structure of the muscle is important for muscle strength, with strength being measured in several ways. Consequently, it is hard to definitively state which muscle is actually strongest.

We have two types of muscle fibre – one that supports long, constant usage exerting low levels of pressure, and one that supports brief, high levels of force. The latter is used during anaerobic activity and these fibres respond better to muscle building.

Genetics can affect muscle strength, as can usage, diet and exercise regimes. Contractions of muscles cause injuries in the muscle fibres and it is the healing of these that actually create muscle strength as the injuries are repaired and overall strengthen the muscle.

"Tendons attach muscles such as biceps to bones, allowing muscles to move elements of our body"

What are muscles made up of?

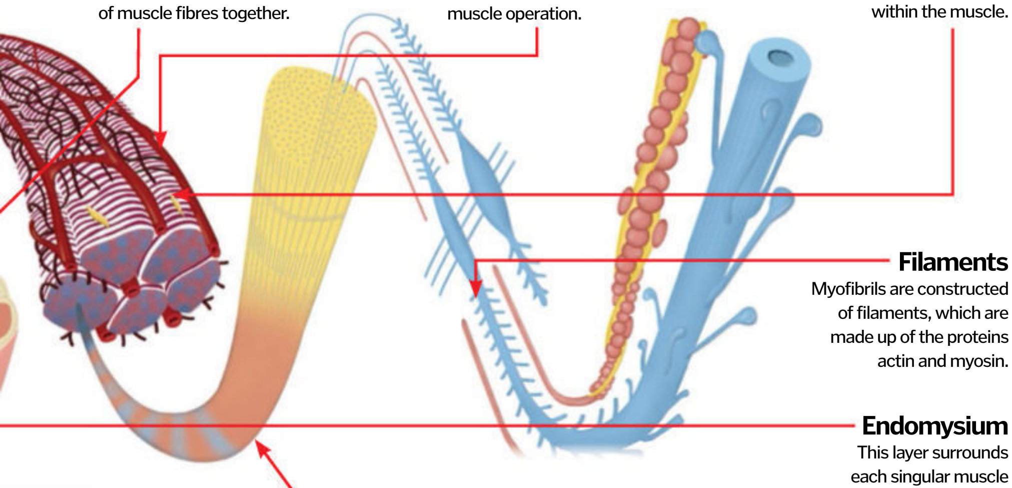
Muscles are made up of numerous cylindrical fibres, which work together to contract and control parts of the body. Muscle fibres are bound together by the perimysium into small bundles, which are then grouped together by the epimysium to form the actual muscle.

Blood vessels and nerves also run through the connective tissue to give energy to the muscle and allow feedback to be sent to the brain. Tendons attach muscles such as biceps and triceps to bones, allowing muscles to move elements of our body as we wish.

Epimysium
The external layer that covers the muscle overall and keeps the bundles of muscle fibres together.

Blood vessel
This provides oxygen and allows the muscle to access energy for muscle operation.

Perimysium
This layer groups together muscle fibres within the muscle.



Filaments
Myofibrils are constructed of filaments, which are made up of the proteins actin and myosin.

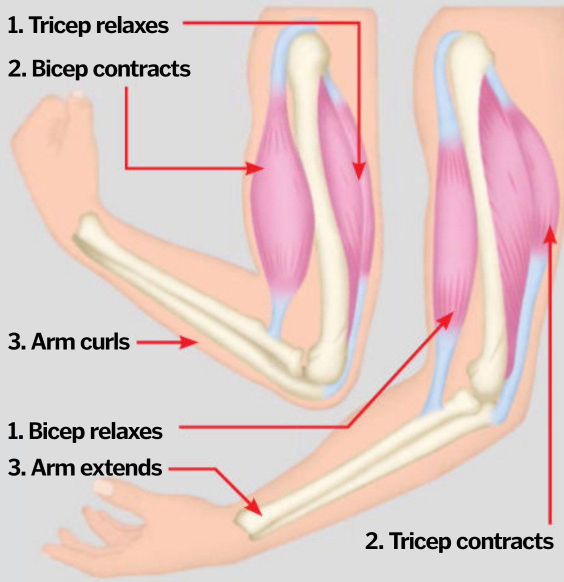
Endomysium
This layer surrounds each singular muscle fibre and keeps the myofibril filaments grouped together.

Tendon
These attach muscle to bones, which in turn enables the muscles to move parts of the body around (off image).

Myofibril
Located within the single muscle fibres, myofibrils are bundles of actomyosin filaments. They are crucial for contraction.

How does the arm flex?

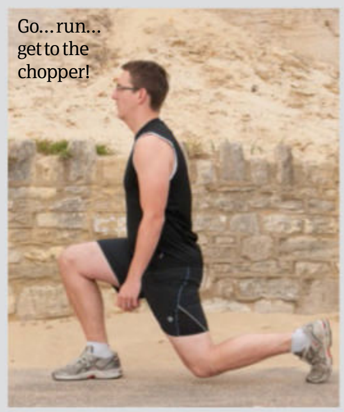
Biceps and triceps are a pair of muscles that work together to move the arm up and down. As the bicep contracts, the triceps will relax and stretch out and consequently the arm will move upwards. When the arm needs to move down, the opposite will occur – with the triceps contracting and the bicep relaxing and being forcibly stretched out by the triceps. The bicep is so named a flexor as it bends a joint, and triceps would be the extensor as it straightens the joint out. Neither of these muscles can push themselves straight, they depend on the other to oppose their movements and stretch them out. Many muscles therefore work in pairs, so-called antagonistic muscles.



What is a pulled muscle, and how does it happen?

They hurt like crazy so here's why it's important to warm up

A pulled muscle is basically a tear in muscle fibres. Sudden movements commonly cause pulled muscles, and often, when an individual has not warmed up appropriately before exercise or is unfit, a tear can occur as the muscle is not prepared for usage. The most common muscle to be pulled is the hamstring, which stretches from the buttock to the knee. A pulled muscle may result in swelling and pain can last for several days before the fibres repair themselves. To prevent pulling muscles, warming up is recommended before any kind of physical exertion.


Go… run… get to the chopper!

Skin colour explained

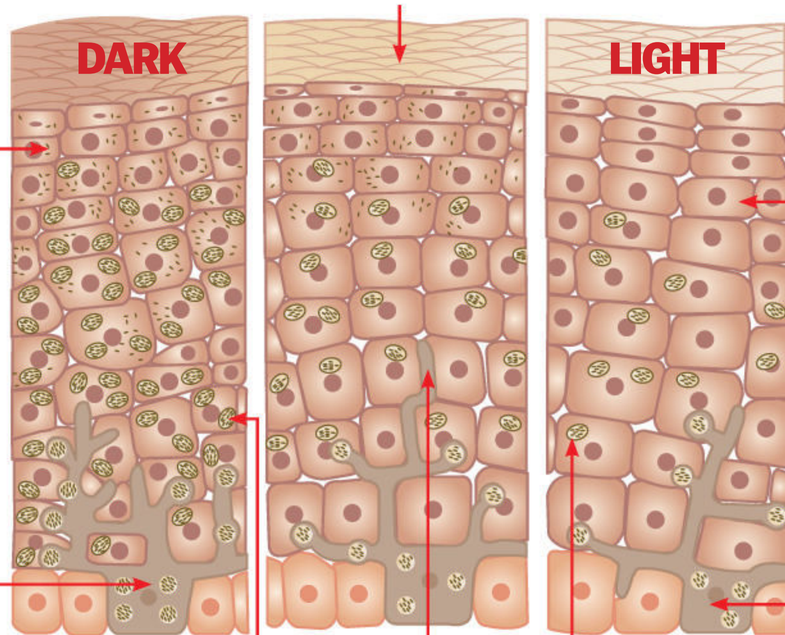
What is melanin and how does it affect the tone of our skin?

The light-absorbing pigment melanin is a chemical substance that gives your skin its natural colouring. Skin can vary from very dark brown to almost completely white due to a combination of your genes and inherited traits and the amount of sunlight to which you're exposed.

Skin colour differs depending on the concentration of melanin present and its distribution throughout the skin's layers. Those with less melanin have lighter skin, while those with more of the pigment have darker skin. Melanin is produced by specialised skin cells called melanocytes in the lower layers of the epidermis and is contained inside a melanosome by a very thin membrane.

Exposure to sunlight stimulates the production of melanin granules. The melanosomes containing the melanin then move out towards the skin's protective keratinocyte cells along branch cells called dendrites. Melanin is then stored in the nuclei of the keratinocytes where it acts as a natural protector against the effects of the Sun's ultraviolet rays. Keratinocytes make up the bulk – around 95 per cent – of the outer layers of the skin and form the barrier between the body and the outside world. They take up melanin which can absorb cancer-causing UV radiation so it doesn't get into the body's internal tissues.

Melanin and skin colour



Keratinocytes
These protective cells are produced in the lower layers of the epidermis. They take up the melanosomes produced by the melanocytes.

Surface
Basal skin cells manufactured in the lower layers of the epidermis grow through the skin to the surface, where they are eventually sloughed away.

Keratinocytes
The keratinocytes of lighter- skinned people take up fewer melanosomes.

Melanocyte
Melanin is made in the melanocytes. People with darker skin, or those who live in regions with greater sunlight exposure, have more active melanocytes.

Dendrite
These branching cells pass melanin to keratinocytes.

Melanocyte
Those with lighter skin have fewer dendrites in their lower layers and their melanocytes are also less active.

Melanosomes
These packets of melanin release melanin granules into the keratinocytes.

Melanosomes
The melanosomes in lighter skin release far fewer melanin granules.

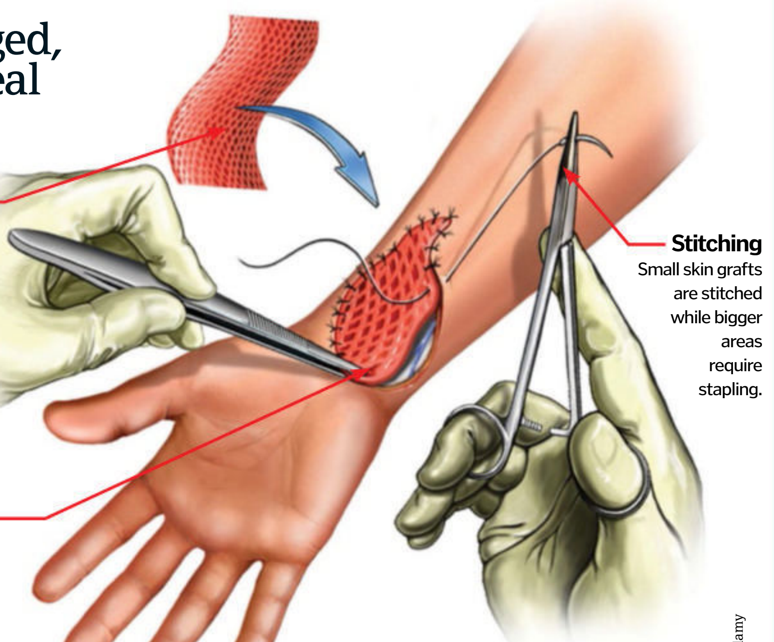
How skin grafts work

When our body's largest organ is damaged, sometimes it needs a helping hand to heal

Skin grafting is a medical procedure where a portion of skin is removed and stitched onto another part of the body. There are many cosmetic and medical reasons why this might be necessary: serious burns, surgery, tattoo removal and some medical conditions (skin cancer or diabetes, for example) might all necessitate skin grafting.

Autografts are skin grafts taken from the patient's own body, usually the buttocks, neck or back of the arm. Depending on the size of the area that it's removed from, it's then stitched or stapled closed again and the new skin applied to the injured area. Allografts and xenografts, meanwhile – taken from other humans and animals, respectively – are temporary grafts.

But perhaps most interesting is the artificial 'skin' called Integra, made of animal collagen that gives the damaged part an organic scaffolding for new skin to grow into. This is usually used in cases of extreme burns where there isn't enough healthy skin for an autograft.



Gauze
A sterile gauze is applied while the skin attaches and a new blood supply establishes.

Donor skin
The donor skin is removed and then applied to the injured area.

Stitching
Small skin grafts are stitched while bigger areas require stapling.

© Alamy

Skin graft surgery

Under the skin

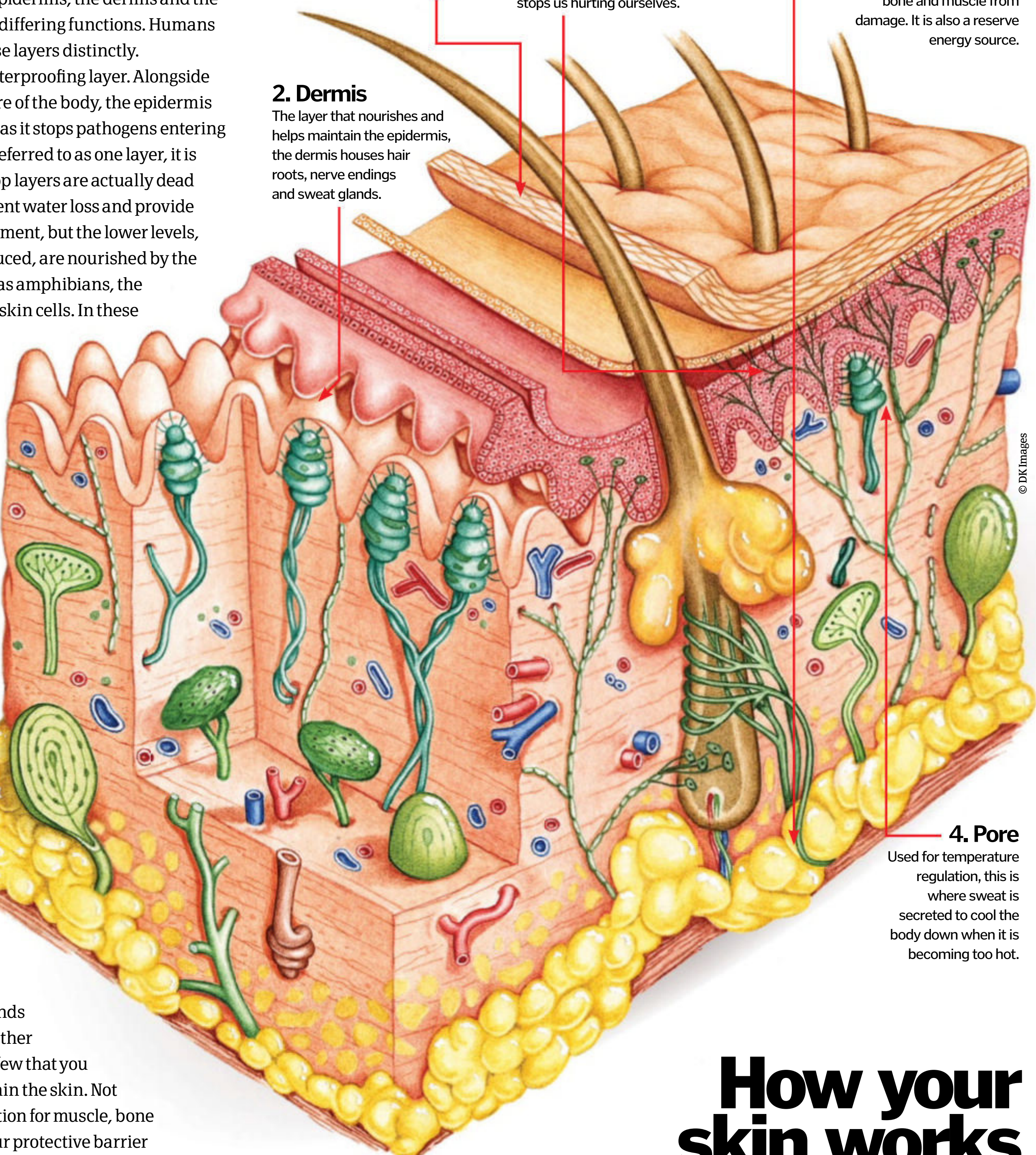
Find out more about the largest organ in your body…

Our skin is the largest organ in our bodies with an average individual skin's surface area measuring around two square metres and accounting for up to 16 per cent of total body weight. It is made up of three distinct layers. These are the epidermis, the dermis and the hypodermis and they all have differing functions. Humans are rare in that we can see these layers distinctly.

The epidermis is the top, waterproofing layer. Alongside helping to regulate temperature of the body, the epidermis also protects against infection as it stops pathogens entering the body. Although generally referred to as one layer, it is actually made up of five. The top layers are actually dead keratin-filled cells which prevent water loss and provide protection against the environment, but the lower levels, where new skin cells are produced, are nourished by the dermis. In other species, such as amphibians, the epidermis consists of only live skin cells. In these cases, the skin is generally permeable and actually may be a major respiratory organ.

The dermis has the connective tissue and nerve endings, contains hair follicles, sweat glands, lymphatic and blood vessels. The top layer of the dermis is ridged and interconnects securely with the epidermis.

Although the hypodermis is not actually considered part of the skin, its purpose is to connect the upper layers of skin to the body's underlying bone and muscle. Blood vessels and nerves pass through this layer to the dermis. This layer is also crucial for temperature regulation, as it contains 50 per cent of a healthy adult's body fat in subcutaneous tissue. These kinds of layers are not often seen in other species, humans being one of few that you can see the distinct layers within the skin. Not only does the skin offer protection for muscle, bone and internal organs, but it is our protective barrier against the environment. Temperature regulation, insulation, excretion of sweat and sensation are just a few more functions of skin.



How your skin works

The skin is made of many more elements than most people imagine

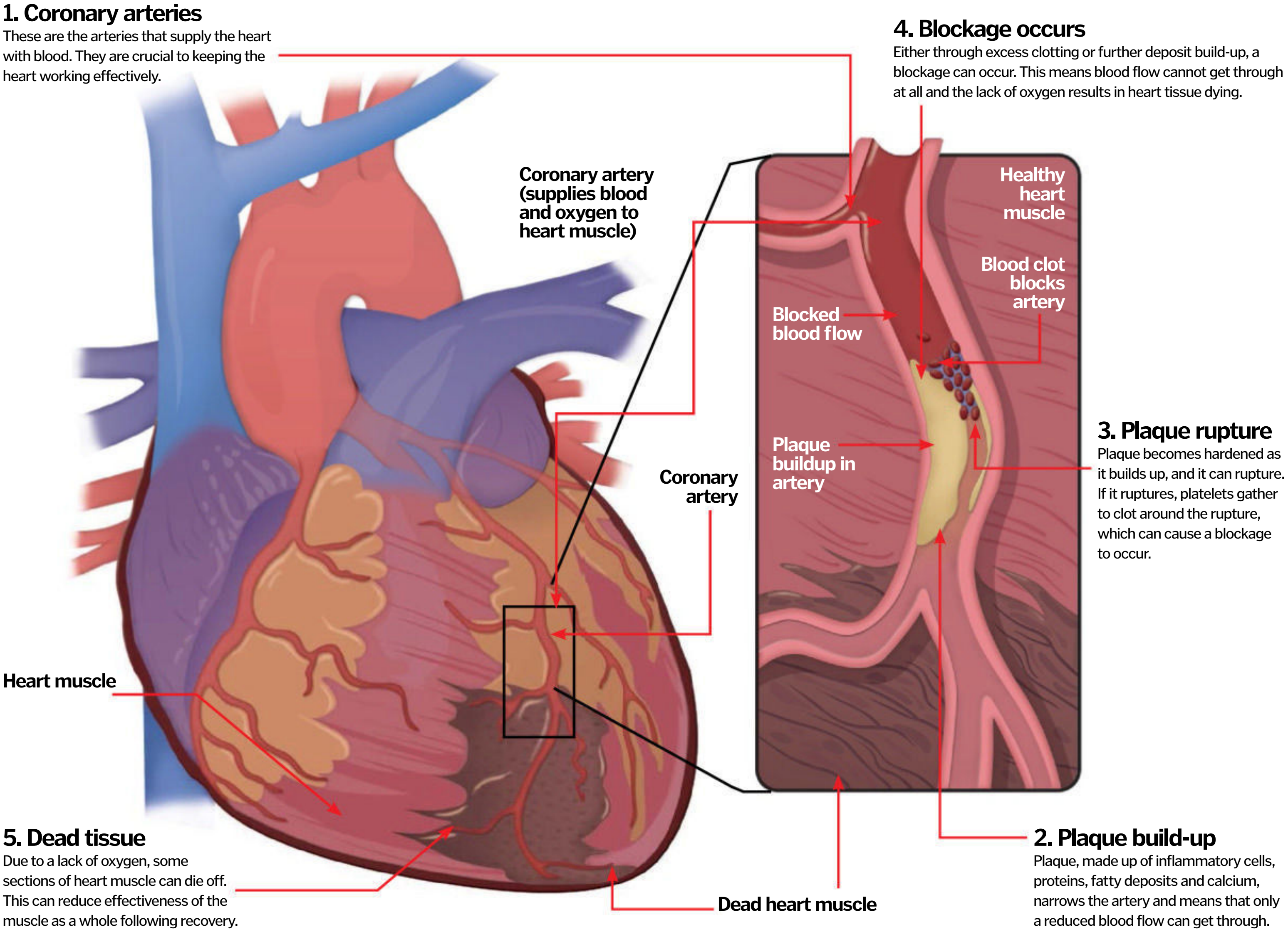
Heart attacks

What causes heart attacks and how do they kill?

A heart attack, also known as a myocardial infarction, occurs when a blockage stops blood oxygenating the heart muscle. If this is not corrected quickly, the muscle tissue that is lacking oxygen can become damaged, or indeed die. The scale of impact on the individual's health after the attack is dependant on how long the blockage occurs for, what artery it affected and what treatment was received. Following the initial attack, heart failure or arrhythmias can occur, both of which may prove fatal to the victim. However, given the right treatment many sufferers go on to make good recoveries and can eventually return to their normal activities.

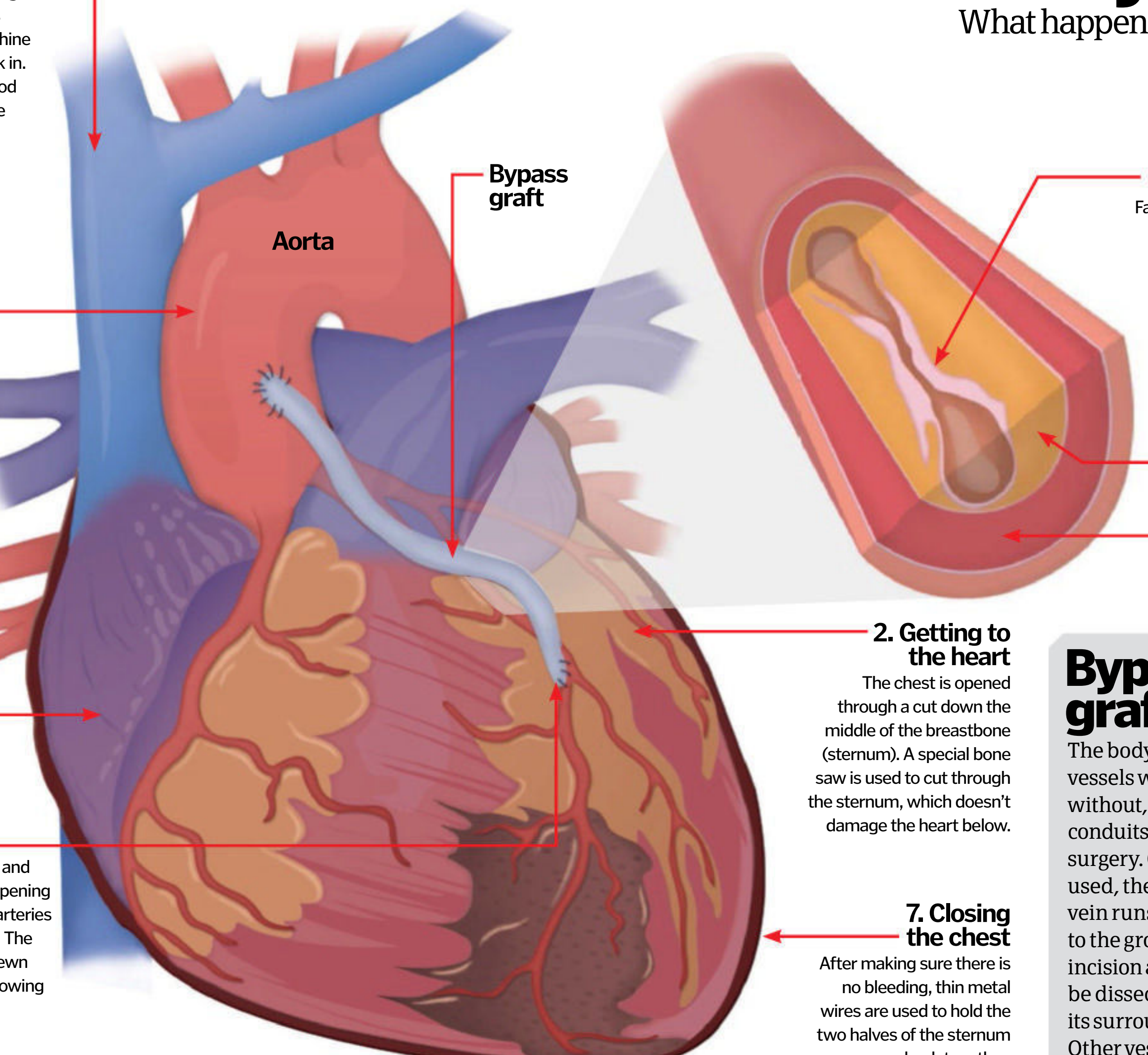
The most common reason for heart attacks worldwide in humans is the generation of coronary artery disease (CAD). This is where arteries are constricted due to plaque build-ups and this layer then ruptures. Blood platelets make their way to the site of rupture and start to form blood clots. If these clots become too large, the narrowed artery will block and a heart attack occurs. Heart attacks can also be caused by coronary artery spasms, but these are rare.

Although some people will be genetically predisposed to heart attacks, individuals can reduce risk by keeping their weight down, watching what they eat, not smoking and exercising regularly.



Heart bypass

What happens in surgery?



How heart bypasses work

When too little blood is getting to the muscles of the heart, a surgeon can bypass the blockages using the body's own vessels

Although the heart pumps oxygenated blood around the body, the heart's muscular walls need their own blood supply. Oxygen-rich blood is delivered to these tissues via small vessels on its surface – the coronary arteries. These arteries can get narrowed or blocked up with cholesterol causing fatty plaques which slow blood flow. At times of exercise, not enough blood gets to the heart muscles, leading to pain due to lack of oxygen – angina. If a vessel becomes completely blocked, no blood gets through, causing a heart attack where the heart muscle dies.

The first way to treat this type of coronary artery disease is with medicines. Secondly, angioplasty can be used, where narrowings in the arteries are stretched using a balloon, placing a stent to keep the vessel open. Finally, a heart bypass operation is an option for some patients.

The surgeon uses healthy vessels from other parts of the patient's body to bypass the blockage, allowing a new route for blood to flow. This delivers higher volumes of the oxygen-rich blood to the heart muscles beyond the blockage, preventing the pain.

Most bypasses are performed by stopping the heart and using a heart-lung bypass machine to deliver oxygenated blood to the body. The new vessels are then sewn into place.

Bypass grafts

The body has certain vessels which it can do without, and these act as conduits for bypass surgery. Commonly used, the long saphenous vein runs from the ankle to the groin. A shallow incision allows the vein to be dissected away from its surrounding tissue. Other vessels often used include small arteries from behind the rib cage (internal mammary artery) or the arms (radial artery).

Stopping the heart

Cardiopulmonary bypass (where a machine takes over the heart's pumping action and the gas exchange function of the lungs) is established to provide oxygenated blood to the rest of the body. Next, the heart is stopped. This is achieved using a potassium-rich solution, pumped down the coronary arteries. This stops the heart contracting. The surgeon can now carefully attach the fresh vessels to bypass the blockages.

Kidney function

How do your kidneys filter waste from the blood to keep you alive?

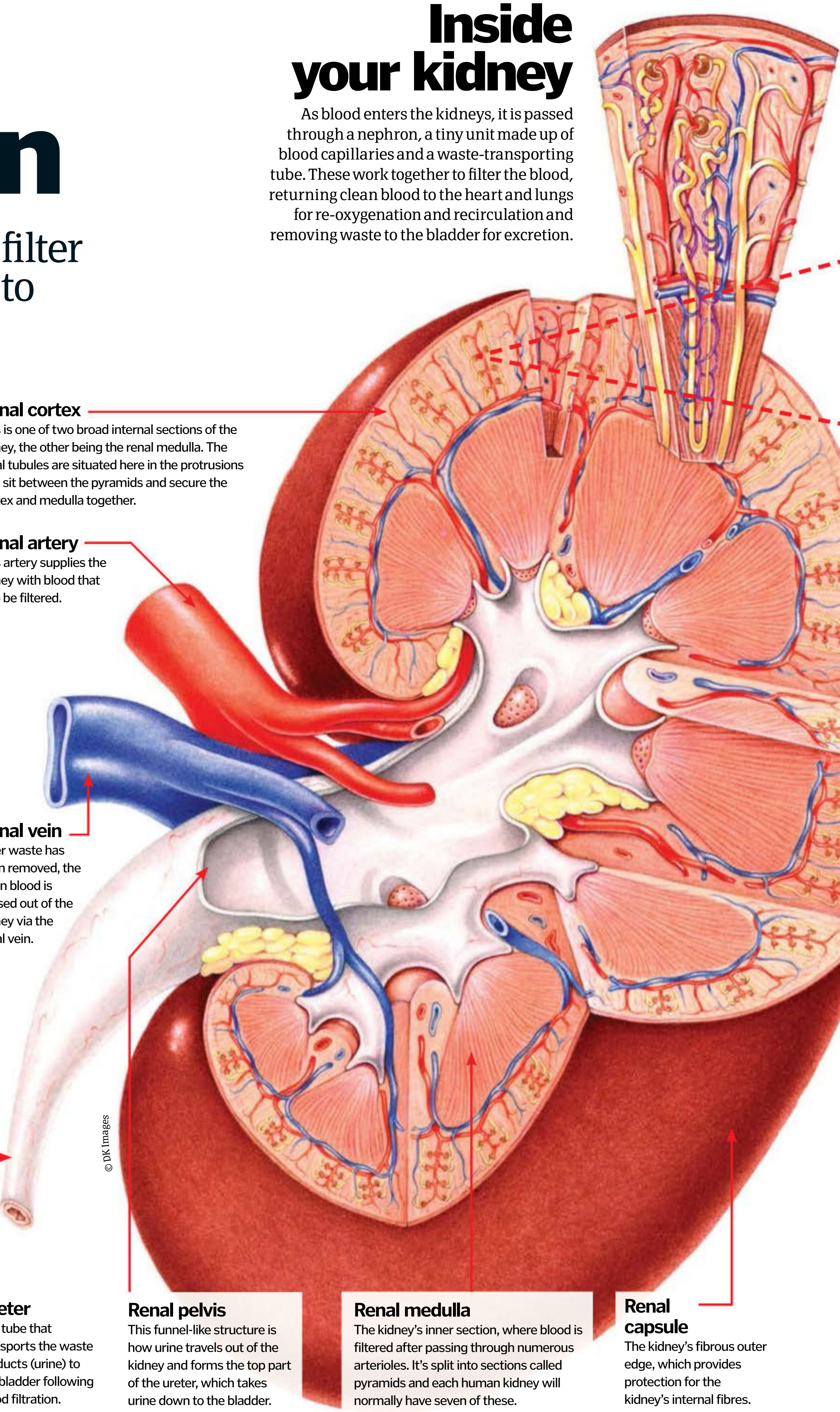
Kidneys are two bean-shaped organs situated halfway down the back just under the ribcage, on each side of the body, and weigh between 115 and 170 grams each, dependent on the individual's sex and size. The left kidney is commonly a little larger than the right and due to the effectiveness of these organs, individuals born with only one kidney can survive with little or no adverse health problems. Indeed, the body can operate normally with a 30-40 per cent decline in kidney function. This decline in function would rarely even be noticeable and shows just how effective the kidneys are at filtering out waste products as well as maintaining mineral levels and blood pressure throughout the body. The kidneys manage to control all of this by working with other organs and glands across the body such as the hypothalamus, which helps the kidneys determine and control water levels in the body.

Each day the kidneys will filter between 150 and 180 litres of blood, but only pass around two litres of waste down the ureters to the bladder for excretion. This waste product is primarily urea – a by-product of protein being broken down for energy – and water, and it's more commonly known as 'urine'. The kidneys filter the blood by passing it through a small filtering unit called a nephron. Each kidney has around a million of these, which are made up of a number of small blood capillaries, called glomerulus, and a urine-collecting tube called the renal tubule. The glomerulus sift the normal cells and proteins from the blood and then move the waste products into the renal tubule, which transports urine down into the bladder through the ureters.

Alongside this, the kidneys also release three hormones (known as erythropoietin, renin and calcitriol) which encourage red blood cell production, aid regulation of blood pressure and aid bone development and mineral balance respectively.

Inside your kidney

As blood enters the kidneys, it is passed through a nephron, a tiny unit made up of blood capillaries and a waste-transporting tube. These work together to filter the blood, returning clean blood to the heart and lungs for re-oxygenation and recirculation and removing waste to the bladder for excretion.



Renal cortex
This is one of two broad internal sections of the kidney, the other being the renal medulla. The renal tubules are situated here in the protrusions that sit between the pyramids and secure the cortex and medulla together.

Renal artery
This artery supplies the kidney with blood that is to be filtered.

Renal vein
After waste has been removed, the clean blood is passed out of the kidney via the renal vein.

Ureter
The tube that transports the waste products (urine) to the bladder following blood filtration.

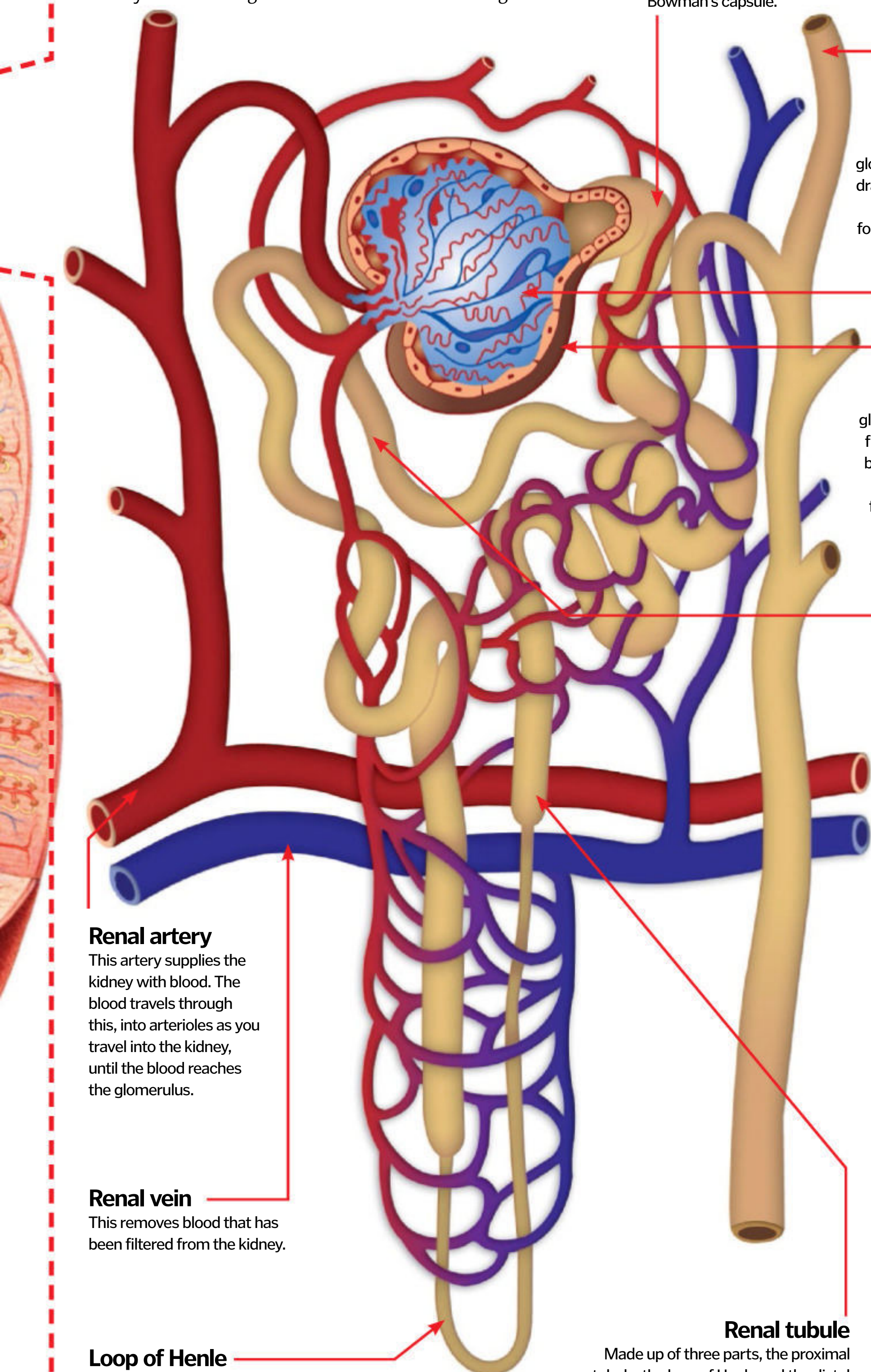
Renal pelvis
This funnel-like structure is how urine travels out of the kidney and forms the top part of the ureter, which takes urine down to the bladder.

Renal medulla
The kidney's inner section, where blood is filtered after passing through numerous arterioles. It's split into sections called pyramids and each human kidney will normally have seven of these.

Renal capsule
The kidney's fibrous outer edge, which provides protection for the kidney's internal fibres.

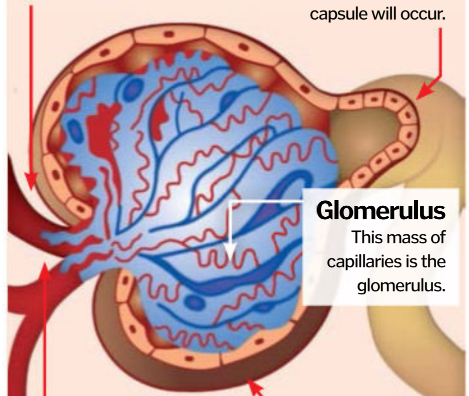
Nephrons – the filtration units of the kidney

Nephrons are the units which filter all blood that passes through the kidneys. There are around a million in each kidney, situated in the renal medulla's pyramid structures. As well as filtering waste, nephrons regulate water and mineral salt by recirculating what is needed and excreting the rest.



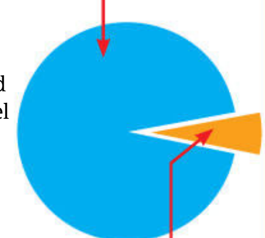
The glomerulus

This group of capillaries is the first step of filtration and a crucial aspect of a nephron. As blood enters the kidneys via the renal artery, it is passed down through a series of arterioles which eventually lead to the glomerulus. This is unusual, as instead of draining into a venule (which would lead back to a vein) it drains back into an arteriole, which creates much higher pressure than normally seen in capillaries, which in turn forces soluble materials and fluids out of the capillaries. This process is known as ultrafiltration and is the first step in filtration of the blood. These then pass through the Bowman's capsule (also know as the glomerular capsule) for further filtration.



What is urine and what is it made of?

Urine is made up of a range of organic compounds such as proteins and hormones, inorganic salts and numerous metabolites. These by-products are often rich in nitrogen and need to be removed from the blood stream through urination. The pH-level of urine is typically around neutral (pH7) but varies depending on diet, hydration levels and physical fitness. The colour of urine is also determined by these factors, with dark-yellow urine indicating dehydration and greenish urine being indicative of excessive asparagus consumption.



Kidney transplants

The kidneys are the body's natural filters. You can survive on just one, but when that fails you may need a transplant

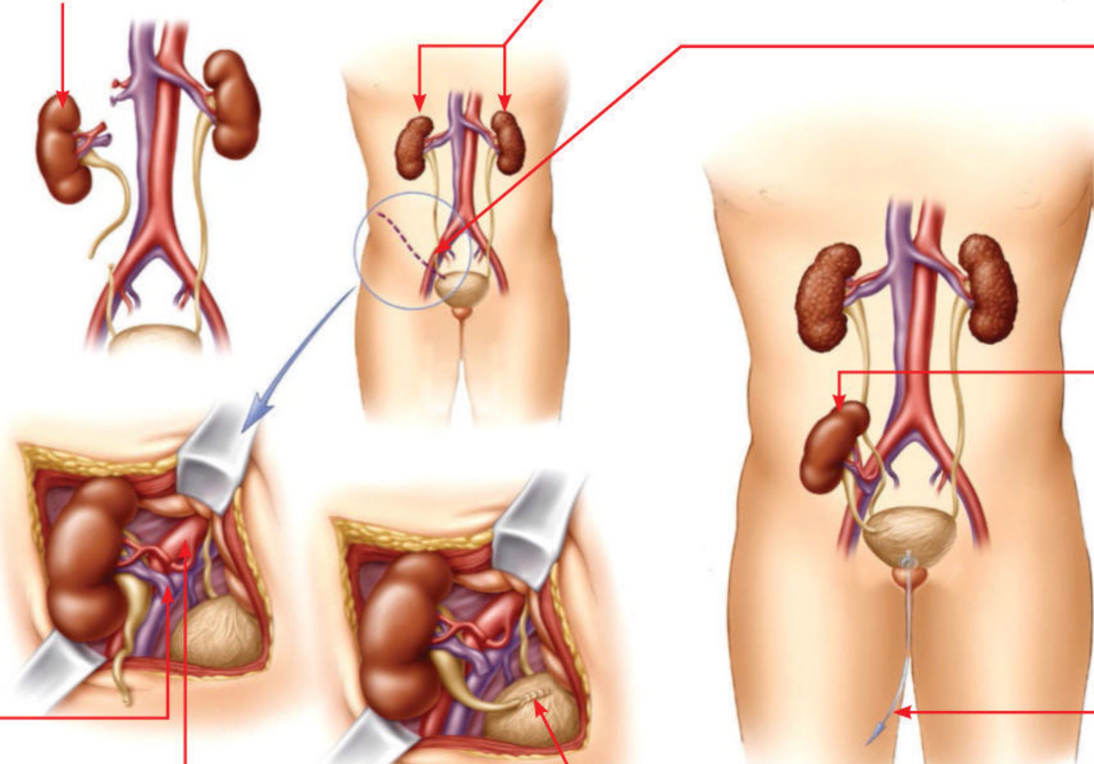
Transplanting organs is a complex process, but it can give a new lease of life to recipients. The kidney is the most frequently transplanted organ, across the globe. However, there is a discrepancy between the number of patients waiting for a transplant and the number of available organs; only around one third of those waiting per year receive their transplant. The number of patients registered for a kidney transplant increases each year, and has risen by 50 per cent since 2000.

Kidney transplants come from two main sources: the living and the recently deceased. If a healthy, compatible family member is willing to donate a kidney, they can survive with just one remaining kidney. In other cases, someone else's tragedy is someone else's fortune. For those who are declared brain-dead, the beating heart will keep the kidneys perfused until they are ready to be removed. In some patients, the ventilator will be switched off and it's a race against time to harvest organs. Either way, consent from the family is needed, even at such an emotional and pressurised time.

When a suitable organ becomes available, it is matched via a national register to a suitable recipient. A 'retrieval' team from a central transplant unit (of which there are 20 based around the UK) will go to whichever hospital the donor is in. They will remove the organs, while the recipient is being prepared in the base hospital. During the tricky operation, the new kidney is 'plumbed' into the pelvis, leaving the old, non-functioning ones in-situ.

How to perform a kidney transplant

Transplanting a kidney is a case of careful and clever plumbing. The first step is to harvest the donor kidney, and then it's a dash to transplant the new kidney into the recipient. When the brain-dead donor is transferred to the operating theatre for organ harvest, they are treated with the same care and respect as if they were still alive. When consent has been given for multiple organ harvest, a cut is made from the top of the chest to the bottom of the pelvis. The heart and lungs are retrieved first, followed by the abdominal organs.



1. The donor
The donor kidney is harvested, including enough length of artery, vein and ureter (which carries urine to the bladder) to allow tension-free implantation into the recipient.

2. Out with the old?
As long as there's no question of cancer, the original kidneys are left in place.

3. Into the pelvis
An incision is made in the lower part of the abdomen to gain access into the pelvis.

4. Make space!
The surgeon will create space in the pelvis, and identify the large vessels which run from the heart to the leg (the iliac arteries and veins). The new kidney's vessels will be connected to these.

5. Plumbing it in
The renal artery and vein are connected to the corresponding iliac artery and vein in the recipient's body. Holes (arteriotomies) are created in the main arteries, and the kidney's vessels are anastomosed (a surgical join between two tubes using sutures).

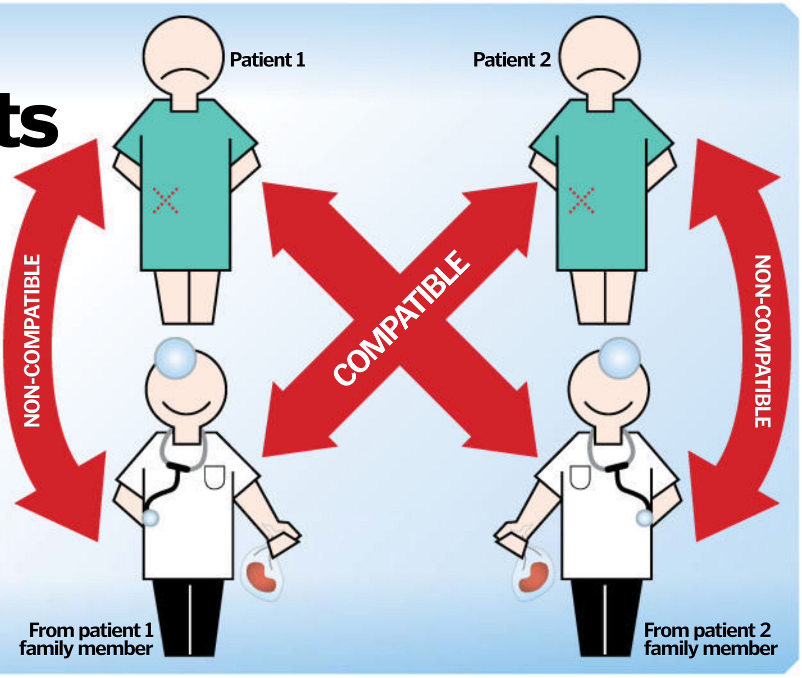
6. The final link
The ureter, which drains urine from the kidney, is connected to the bladder. This allows the kidney to function in the same way as one of the original kidneys.

7. What's that lump?
The new kidney can be felt underneath the scar in the recipient. These patients are often recruited to medical student exams .

8. Catheter
A catheter is left in-situ for a short while, so that the urine output of the new kidney can be measured exactly.

Domino transplants

Patient 1 needs a new kidney but their family member isn't compatible. Patient 2 also needs a kidney and has an incompatible family member as well. However, patient 2's relation is compatible with patient 1 and vice versa. The surgeon arranges a swap – a 'paired' transplant. A longer line of patients and family members swapping compatible kidneys can be arranged – a 'daisy-chain' transplant. A 'good Samaritan' donor, who isn't related to any of the recipients, can start the process. This first recipient's family member will subsequently donate to someone else – a 'domino' transplant effect which can go on for several cycles.

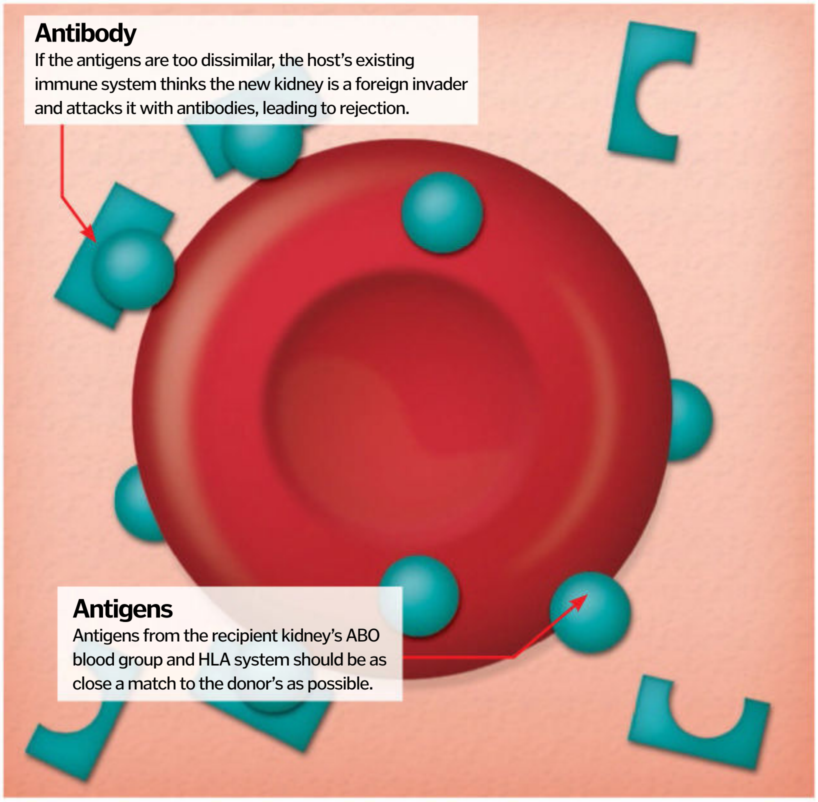


Who is suitable?

Of the several million people in the UK with kidney disease, only around 50,000 will develop end-stage renal failure (ESRF). For these people, dialysis or kidney transplantation are the only options. Kidney damage from diabetes is the most common cause of transplantation. Other causes include damage from high blood pressure, chronic kidney scarring (chronic pyelonephritis) and polycystic kidney disease (the normal kidney tissue is replaced with multiple cysts); many other less common causes exist also.

Patients must be selected carefully due to the scarcity of organs. Those with widespread cancer, severely calcified arteries, persistent substance abuse and unstable mental problems mean that transplants are likely to fail and so these patients are unsuitable to receive a precious kidney transplant.

"Patients are monitored for the rest of their lives"



When things go wrong…

Kidneys need to be carefully matched to suitable donors, or rejection of the new organ will set in fast. Rejection occurs when the host body's natural antibodies think the new tissue is a foreign invader and attacks; careful pre-operative matching helps limit the degree of this attack. The most important match is via the ABO blood group type – the blood group must match or rejection is fast and aggressive. Next, the body's HLA (human leukocyte antigen) system should be a close a match as possible, although it doesn't need to be perfect. Incorrect matches here can lead to rejection over longer periods of time. After the operation, patients are started on anti-rejection medicines which suppress the host's immune system (immunosuppressants such as Tacrolimus, Azathioprine or Prednisolone). Patients are monitored for the rest of their lives for signs of rejection. These immunosuppressants aren't without their risks – since they suppress the body's natural defences, the risks of infections and cancers are higher.

Pack carefully!

The transport of harvested organs is time critical – the sooner the surgeon can put them into the recipient the better. As soon as blood stops flowing to the harvested tissue, the lack of oxygen damages these cells, which is called ischaemia. The retrieval team have a few tricks up their sleeves to maximise the viability of the precious cargo they carry.

In the operating theatre, just before they remove the harvested kidney, it is flushed clean of blood with a special cold, nutrient-rich solution. Once removed, it is quickly put in a sterile container with ice. The most modern technique is to use a cold perfusion machine instead of ice, which pumps a cooled solution through the kidney and improves its lasting power. While hearts and lungs can only last around four hours, kidneys can last 24-48 hours. Transfer of the affected organ is done via the fastest method possible; this often involves using helicopters or police escorts.

All of these methods prolong the preservation time of the kidney, although once 'plugged' back in, it can take a few days for the kidney to start working properly (especially if harvested from a non-heart-beating donor).

Useless body parts

Why have humans and other animals stopped using certain organs and functions which were once crucial for survival?

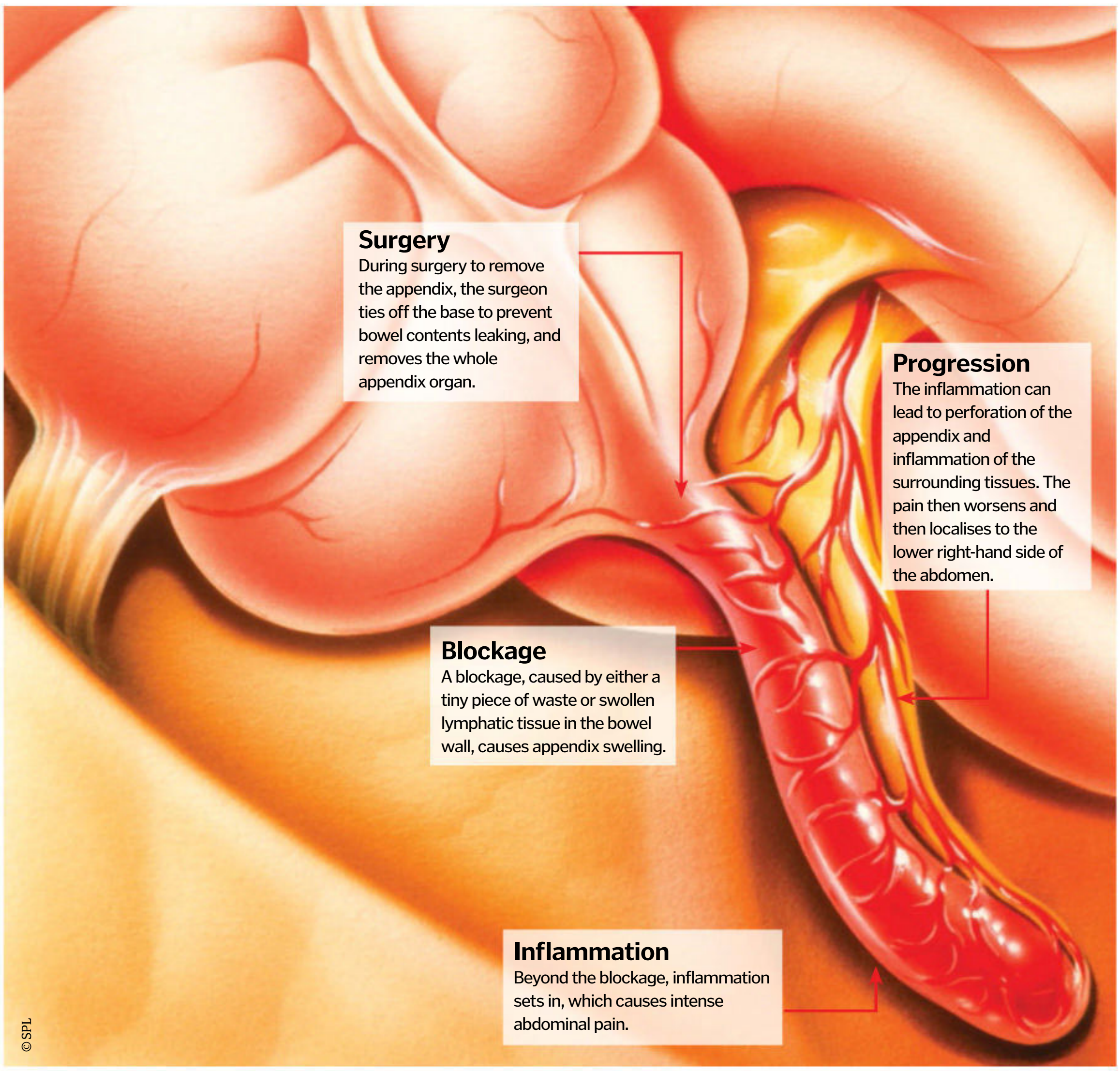
Charles Darwin is one of history's most famous naturalists. Living in the 19th Century, he became celebrated for his theories on evolution. In his seminal work *On The Origin Of Species* he described how similar animals were likely to be related by common ancestors, rather than be completely unrelated. As subsequent generations are born, traits and features that did not bring a survival benefit to that species were eliminated. That, in a nutshell, is the theory of evolution.

As a consequence, some organs and traits left in the body lose their function and are no longer used. This applies to modern human beings as much as other creatures; some of our physical attributes and behavioural responses are functional in other animals, but they do not seem to be of any benefit to us; such as the appendix and your tailbone. These evolutionary remnants that no longer serve any purpose are called vestigial organs, though this can apply as much to behaviour and other body structures as it does to actual organs.

Evolution has also adapted some existing features to help us in new ways, in a process known as exaptation. For example, birds' wings not only help them to fly but keep them warm too. These changes may take thousands of years to develop, and in some cases the original role is eventually eliminated altogether.

Appendicitis in focus

What happens when your appendix gets inflamed?



Evolution's leftovers

1 Appendix
The best known of the vestigial organs, the appendix is used in animals to help digest cellulose found in grass, but in humans it serves no clear function now.

2 Tailbone

The hard bone at the bottom of your spine, the coccyx, is a remnant of our evolutionary ancestors' tail. It has no function in humans, but you could break it if you fall over.

3 Goosebumps
Animals use body hair for insulation from the cold, by trapping a warm layer of air around the body. Each hair can stand on end when its own tiny muscle contracts, but as human beings have lost most of their body hair, a jumper is more effective.

4 Plica semilunaris

The fleshy red fold found in the corner of your eye used to be a transparent inner eyelid, which is still present in both reptiles and birds.

5 Wisdom teeth
These teeth emerge during our late teens in each corner of the gums. Our ancestors used them to help chew dense plant matter, but they have no function today, but can cause a lot of pain.

How the spleen works

Perhaps not as well known as famous organs like the heart, the spleen serves vital functions that help keep us healthy

The spleen's main functions are to remove old blood cells and fight off infection. Red blood cells have an average life span of 120 days. Most are created from the marrow of long bones, such as the femur. When they're old, it's the spleen's job to identify them, filter them out and then break them down. The smaller particles are then sent back into the bloodstream, and either recycled or excreted from other parts of the body. This takes place in the 'red pulp', which are blood vessel-rich areas of the spleen that make up about three-quarters of its structure.

The remainder is called 'white pulp', which are areas filled with different types of immune cell (such as lymphocytes). They filter out and destroy foreign pathogens, which have invaded the body and are circulating in the blood. The white pulp breaks them down into smaller, harmless particles.

It is surrounded by a thin, fragile capsule and so is prone to injury. It sits beneath the lower ribs on the left-hand side of your body, which affords it some protection, but car crashes, major sports impacts and knife wounds can all rupture the organ. In the most serious cases, blood loss can endanger the person's life, and in these situations it needs to be removed by a surgeon. Since this reduces the body's ability to fight infections, some people will need to take antibiotics to boost their immunity for the rest of their lives.

The immune system

Although the red blood that flows through our bodies gets all the glory, the transparent lymphatic fluid is equally important. It has its own body-wide network which follows blood vessel flow closely and allows for the transport of digested fats, immune cells and more…

Spleen
One of the master co-ordinators that staves off infections and filters old red blood cells. It contains a number of lymphocytes that recognise and destroy invading pathogens present in the blood as it flows through the spleen.

Thymus
A small organ that sits just above the heart and behind the sternum. It teaches T-lymphocytes to identify and destroy specific foreign bodies. Its development is directly related to hormones in the body so it's only present until puberty ends; adults don't need one.

Tonsils
These are masses of lymphoid tissue at the back of the throat and can be seen when the mouth is wide open. They form the first line of defence against inhaled foreign pathogens, although they can become infected themselves, causing tonsillitis.

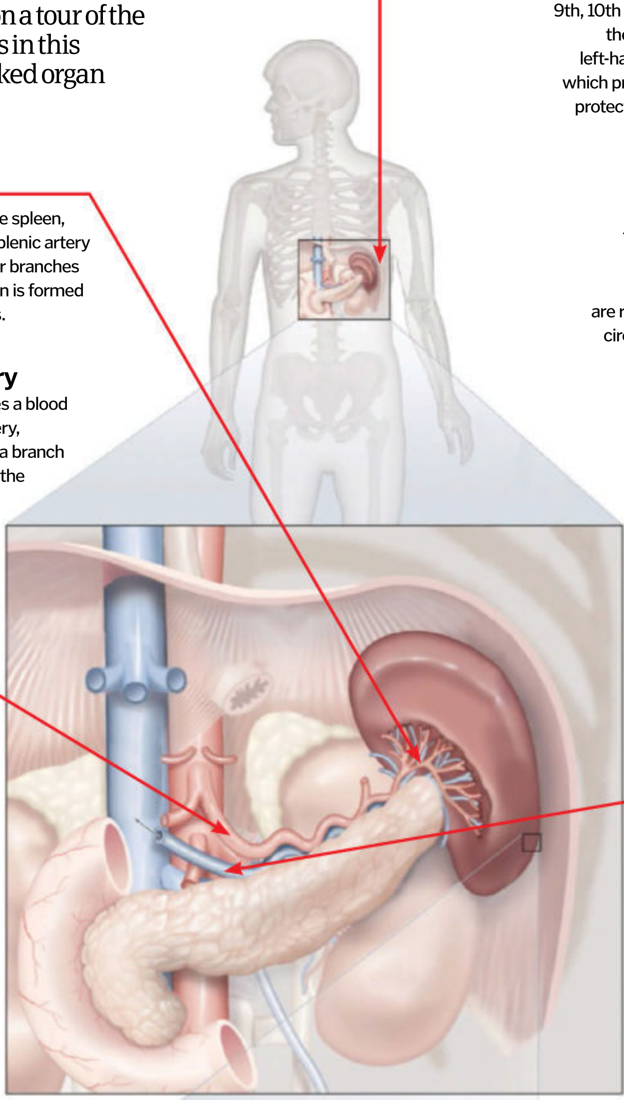
Adenoids
These are part of the tonsillar system that are only present in children up until the age of five; in adults they have disappeared. They add an extra layer of defence in our early years.

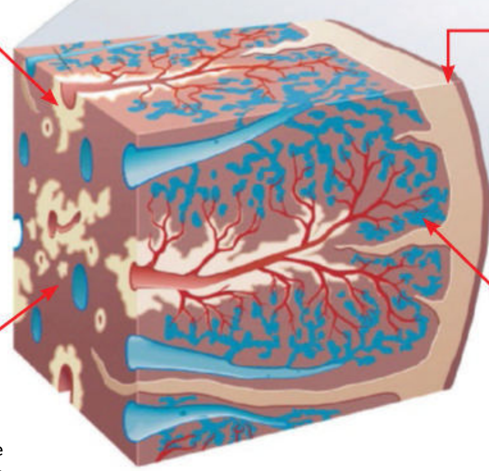
Bone marrow
This forms the central, flexible part of our long bones (eg femur). Bone marrow is essential as it produces our key circulating cells, including red blood cells, white blood cells and platelets. The white blood cells mature into different types (eg lymphocytes and neutrophils), which serve as the basis of the human immune system.

Lymph nodes
These are small (about 1cm/0.4in) spherical nodes that are packed with macrophages and lymphocytes to defend against foreign agents. These are often linked in chains and are prevalent around the head, neck, axillae (armpits) and groin.

Inside the spleen

We take you on a tour of the major features in this often-overlooked organ





How the liver works

The human liver is the ultimate multitasker – it performs many different functions all at the same time without you even asking

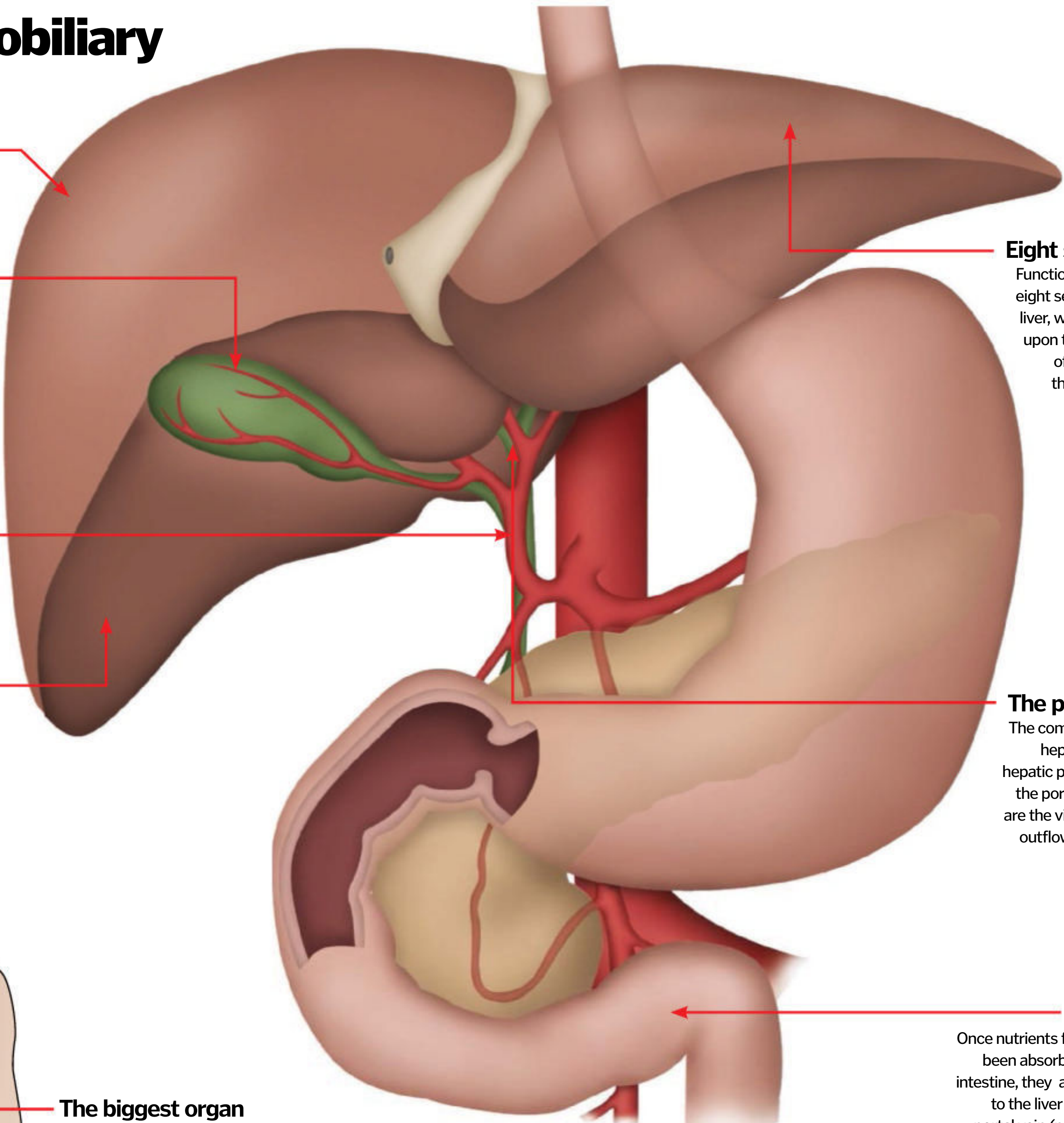
The liver is the largest internal organ in the human body and, amazingly, has over 500 different functions. In fact, it is the second most complex organ after the brain and is intrinsically involved in almost every aspect of the body's metabolic processes.

The liver's main functions are energy production, removal of harmful substances and the production of crucial proteins. These tasks are carried out within liver cells, called hepatocytes, which sit in complex arrangements to maximise their overall efficiency.

The liver is the body's main powerhouse, producing and storing glucose as a key energy source. It is also responsible for breaking down complex fat molecules and building them up into cholesterol and triglycerides, which the body needs but in excess are bad. The liver makes many complex proteins, including clotting factors which are vital in arresting bleeding. Bile, which helps digest fat in the intestines, is produced in the liver and stored in the adjacent gallbladder.

The liver also plays a key role in detoxifying the blood. Waste products, toxins and drugs are processed here into

The hepatobiliary region



Two halves
The liver is anatomically split into two halves: left and right. There are four lobes, and the right lobe is the largest.

The gallbladder
The gallbladder and liver are intimately related. Bile, which helps digest fat, is produced in the liver and stored in the gallbladder.

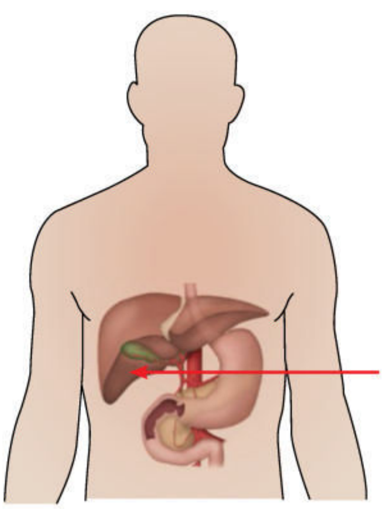
The common bile duct
This duct is small, but vital in the human body. It carries bile from the liver and gallbladder into the duodenum where it helps digest fat.

Feel your liver
Take a deep breath in and feel just under the right lower edge of your ribs – in some people the lower edge of the liver can be felt.

Eight segments
Functionally, there are eight segments of the liver, which are based upon the distribution of veins draining these segments.

The portal triad
The common bile duct, hepatic artery and hepatic portal vein form the portal triad, which are the vital inflows and outflows for this liver.

Digestion
Once nutrients from food have been absorbed in the small intestine, they are transported to the liver via the hepatic portal vein (not shown here) for energy production.

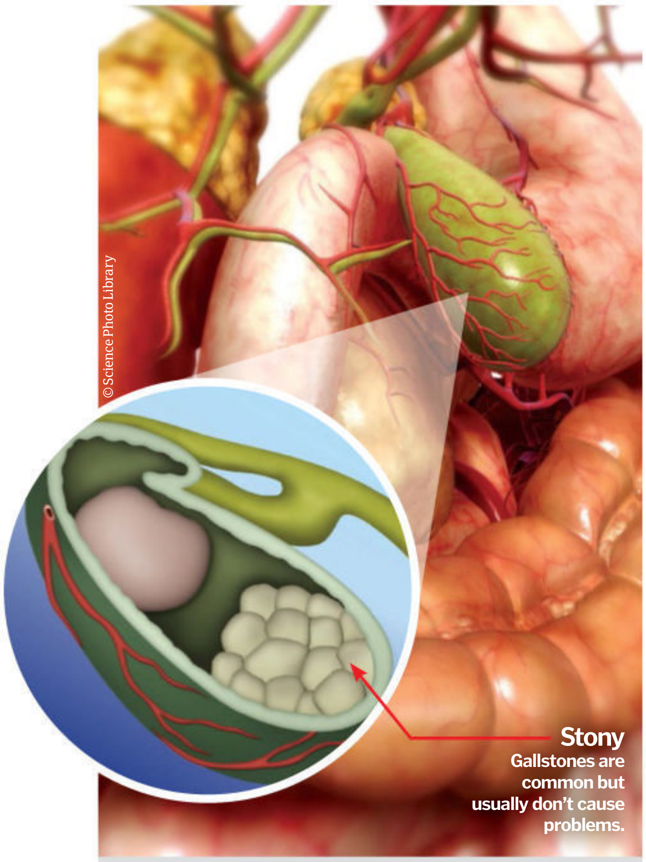


The biggest organ
The liver is the largest of the internal organs, sitting in the right upper quadrant of the abdomen, just under the rib cage and attached to the underside of the diaphragm.

> *"The liver also breaks down old blood cells and recycles hormones such as adrenaline"*

forms which are easier for the rest of the body to use or excrete. The liver also breaks down old blood cells, produces antibodies to fight infection and recycles hormones such as adrenaline. Numerous essential vitamins and minerals are stored in the liver: vitamins A, D, E and K, iron and copper.

Such a complex organ is also unfortunately prone to diseases. Cancers, infections (hepatitis) and cirrhosis (a form of fibrosis often caused by excess alcohol consumption) are just some of those which can affect the liver.



Stony
Gallstones are common but usually don't cause problems.

The gallbladder

Bile, a dark green slimy liquid, is produced in the hepatocytes and helps to digest fat. It is stored in a reservoir which sits on the under-surface of the liver, to be used when needed. This reservoir is called the gallbladder. Stones can form in the gallbladder (gallstones) and are very common, although most don't cause problems. In 2009, just under 60,000 gallbladders were removed from patients within the NHS making it one of the most common operations performed; over 90 per cent of these are removed via keyhole surgery. Most patients do very well without their gallbladder and don't notice any changes at all.

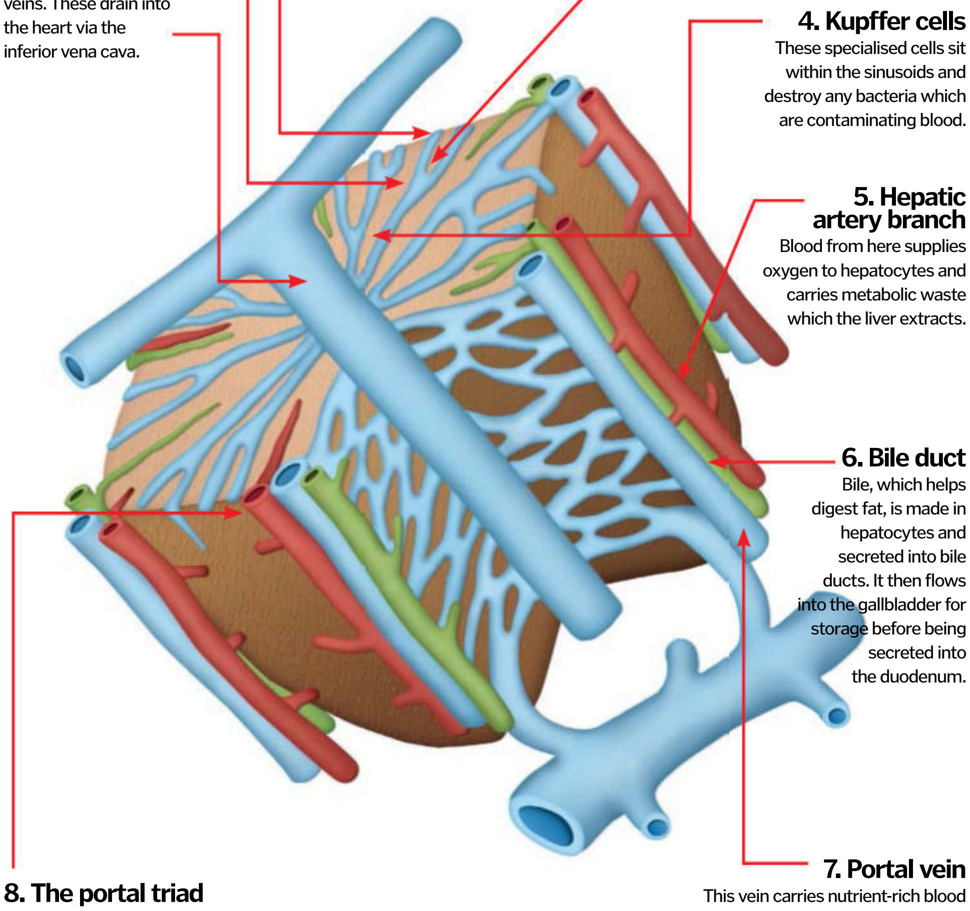
A high demand organ

The liver deals with a massive amount of blood. It is unique because it has two blood supplies. 75 per cent of this comes directly from the intestines (via the hepatic portal vein) which carries nutrients from digestion, which the liver processes and turns into energy. The rest comes from the heart, via the hepatic artery (which branches from the aorta), carrying oxygen which the liver needs to produce this energy. The blood flows in tiny passages in between the liver cells where the many metabolic functions occur. The blood then leaves the liver via the hepatic veins to flow into the biggest vein in the body – the inferior vena cava.

Liver lobules

The functional unit which performs the liver's tasks

The liver is considered a 'chemical factory,' as it forms large complex molecules from smaller ones brought to it from the gut via the blood stream. The functional unit of the liver is the lobule – these are hexagonal-shaped structures comprising of blood vessels and sinusoids. Sinusoids are the specialised areas where blood comes into contact with the hepatocytes, where the liver's biological processes take place.



1. The lobule
This arrangement of blood vessels, bile ducts and hepatocytes form the functional unit of the liver.

2. The hepatocyte
These highly active cells perform all of the liver's key metabolic tasks.

3. Sinusoids
These blood filled channels are lined by hepatocytes and provide the site of transfer of molecules between blood and liver cells.

4. Kupffer cells
These specialised cells sit within the sinusoids and destroy any bacteria which are contaminating blood.

5. Hepatic artery branch
Blood from here supplies oxygen to hepatocytes and carries metabolic waste which the liver extracts.

6. Bile duct
Bile, which helps digest fat, is made in hepatocytes and secreted into bile ducts. It then flows into the gallbladder for storage before being secreted into the duodenum.

7. Portal vein
This vein carries nutrient-rich blood directly from the intestines, which flows into sinusoids for conversion into energy within hepatocytes.

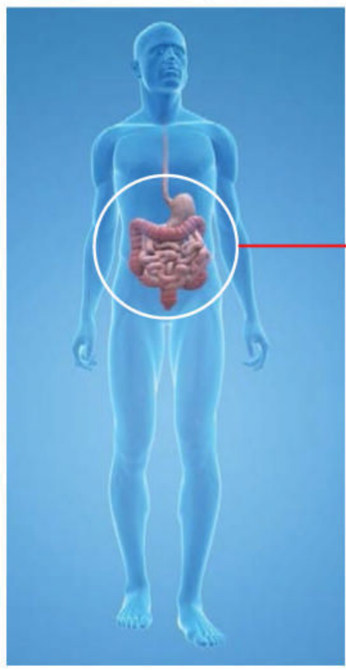
8. The portal triad
The hepatic artery, portal vein and bile duct are known as the portal triad. These sit at the edges of the liver lobule and are the main entry and exit routes for the liver.

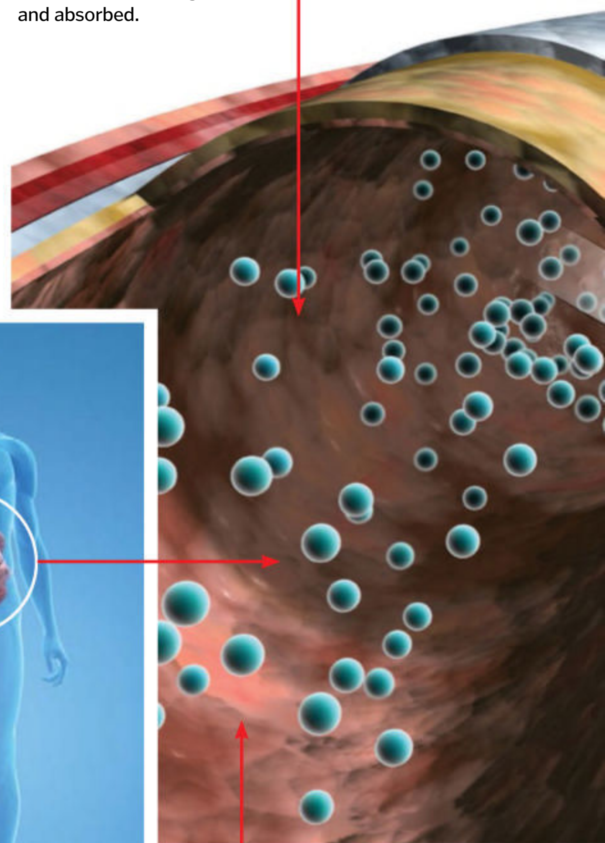
9. Central vein
Blood from sinusoids, now containing all of its new molecules, flows into central veins which then flow into larger hepatic veins. These drain into the heart via the inferior vena cava.

The surface area of the small intestine is huge – in fact, rolled flat it would cover a tennis court!

Structure of the small intestine

Examine the anatomy of this vital organ in the human digestive tract





Lumen
This is the space inside the small intestine in which the food travels to be digested and absorbed.

Mucosa
The internal lining of the small intestine where the plicae circulares (mucosal folds) and villi are situated.

Mucosal folds
These line the small intestine to increase surface area and help push the food on its way by creating a valve-like structure, stopping food travelling backwards.

Submucosa
This supports the mucosa and connects it to the layers of muscle (muscularis) that make up the exterior of the small intestine.

Exploring the small intestine

Crucial for getting the nutrients we need from the food we eat, how does this digestive organ work?

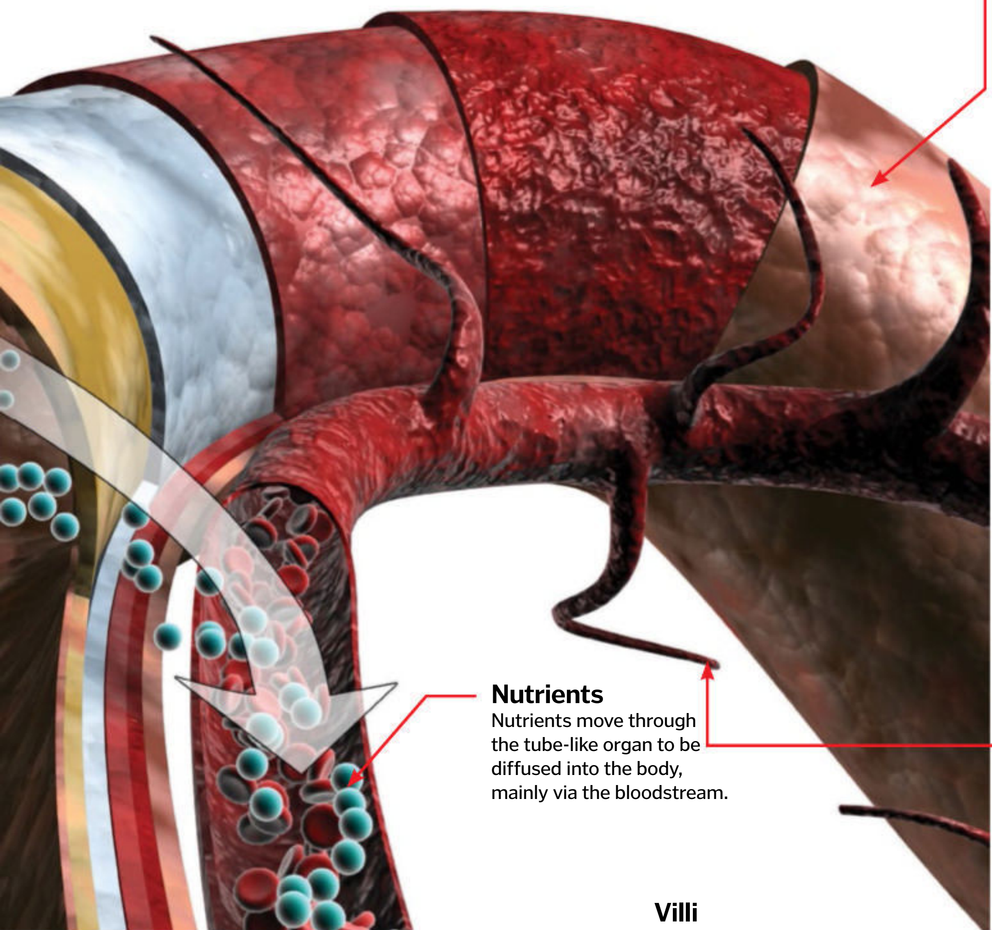
The small intestine is one of the most important elements of our digestive system, which enables us to process food and absorb nutrients. On average, it sits at a little over six metres (19.7 feet) long with a diameter of 2.5-3 centimetres (1-1.2 inches), and it's made up of three distinctive parts: the duodenum, jejunum and the ileum.

The duodenum connects the small intestine to the stomach and is the key place for further enzyme breakdown, following the stomach turning food into an amino acid state. While the duodenum is very important in breaking food down, using bile and enzymes from the gallbladder, liver and pancreas, it is the shortest element of the small bowel, only averaging about 30 centimetres (11.8 inches).

The jejunum follows the duodenum and its primary function is to encourage absorption of carbohydrates and proteins by passing the broken-down food molecules through an area with a large surface area so they can enter the bloodstream. Villi – small finger-like structures – and mucosal folds line the passage and increase the surface area dramatically to aid this process.

The ileum is the final section of the small bowel and serves to catch nutrients that may have been missed, as well as absorbing vitamin B12 and bile salts.

Peristalsis is the movement used by the small intestine to push the food through to the large bowel, where waste matter is stored for a short period then disposed of via the colon. This process is generated by a series of muscles which make up the organ's outer wall.



Serosa
This protective outer layer stops the small intestine from being damaged by other organs.

Nutrients
Nutrients move through the tube-like organ to be diffused into the body, mainly via the bloodstream.

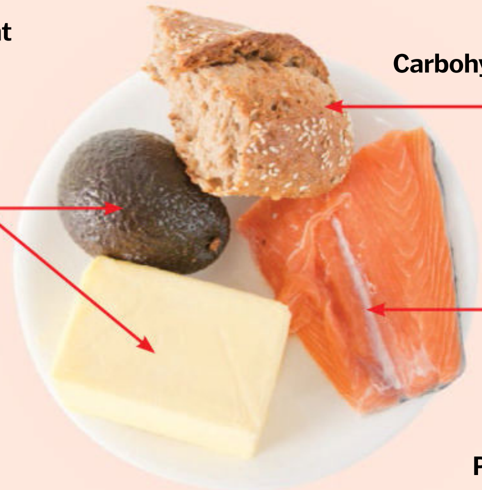
Blood vessels
These sit close to the small intestine to allow easy diffusion of nutrients into the bloodstream.

Longitudinal muscle layer
This contracts and extends to help transport food with the circular muscle layer.

Circular muscle layer
This works in partnership with the longitudinal muscle layer to push the food down via a process called peristalsis.

What exactly are nutrients?

There are three main types of nutrient that we process in the body: lipids (fats), carbohydrates and proteins. These three groups of molecules are broken down into sugars, starches, fats and smaller, simpler molecule elements, which we can absorb through the small intestine walls and that then travel in the bloodstream to our muscles and other areas of the body that require energy or to be repaired. We also need to consume and absorb vitamins and minerals that we can't synthesise within the body, eg vitamin B12 (prevalent in meat and fish).



Fat

Carbohydrate

Protein

A closer look at villi

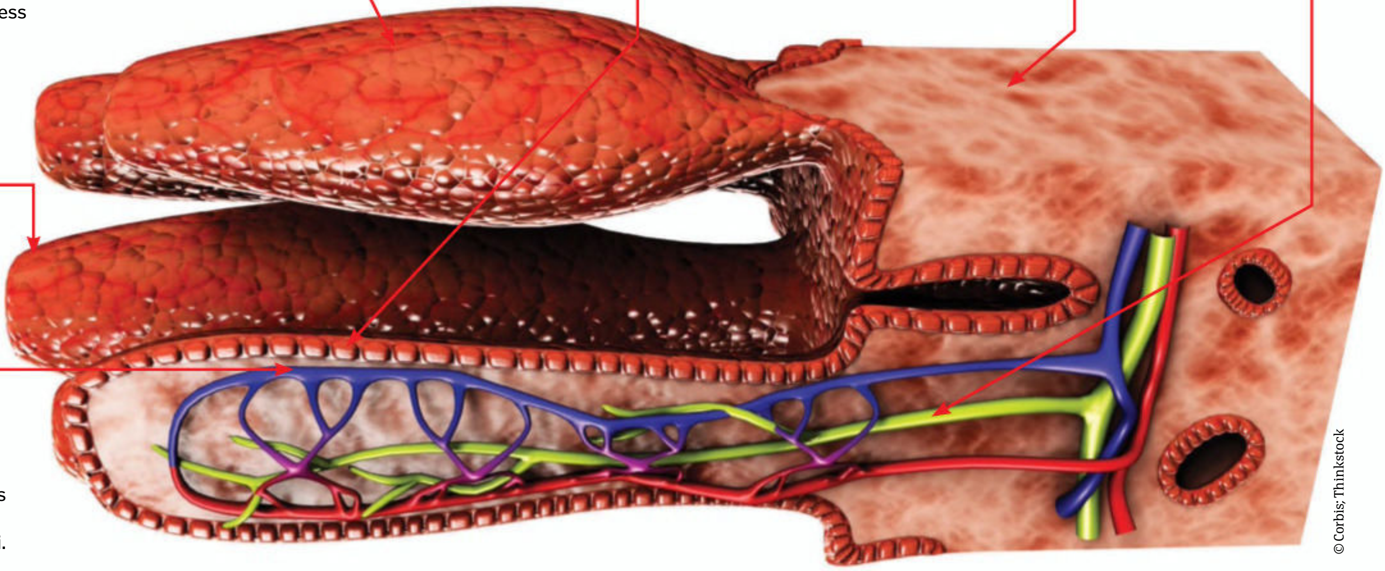
What role do these little finger-like protrusions play in the bowel?

Villi
Villi are tiny finger-like structures that sit all over the mucosa. They help increase the surface area massively, alongside the mucosal folds.

Epithelium (epithelial cells)
These individual cells that sit in the mucosa layer are where individual microvilli extend from.

Mucosa
The lining of the small intestine on which villi are located.

Lacteal
The lacteal is a lymphatic capillary that absorbs nutrients that can't pass directly into the bloodstream.

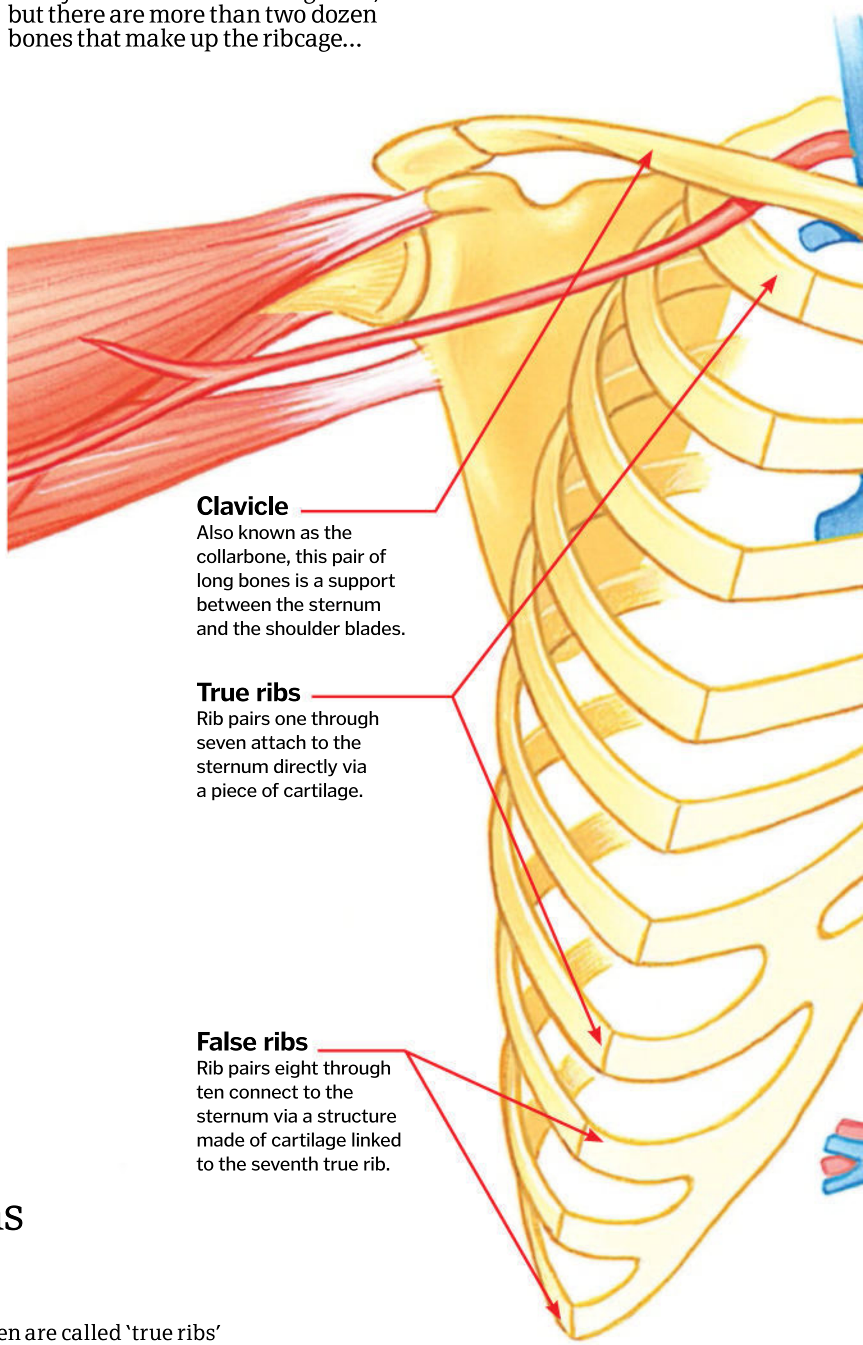


Microvilli
These are a mini version of villi and sit on villi's individual epithelial cells.

Capillary bed
These absorb simple sugars and amino acids as they pass through the epithelial tissue of the villi.

Inside the thoracic cavity

It may not look like it at first glance, but there are more than two dozen bones that make up the ribcage…



The human ribcage

Ribs are not merely armour for the organs inside our torsos, as we reveal here…

The ribcage – also known as the thoracic cage or thoracic basket – is easily thought of as just a framework protecting your lungs, heart and other major organs. Although that is one key function, the ribcage does so much more. It provides vital support as part of the skeleton and, simply put, breathing wouldn't be possible without it.

All this means that the ribcage has to be flexible. The conical structure isn't just a rigid system of bone – it's both bone and cartilage. The cage comprises 24 ribs, joining in the back to the 12 vertebrae making up the middle of the spinal column.

The cartilage portions of the ribs meet in the front at the long, flat three-bone plate called the sternum (breastbone). Or rather, most of them do. Rib pairs one through seven are called 'true ribs' because they attach directly to the sternum. Rib pairs eight through ten attach indirectly through other cartilage structures, so they're referred to as 'false ribs'. The final two pairs – the 'floating ribs' – hang unattached to the sternum.

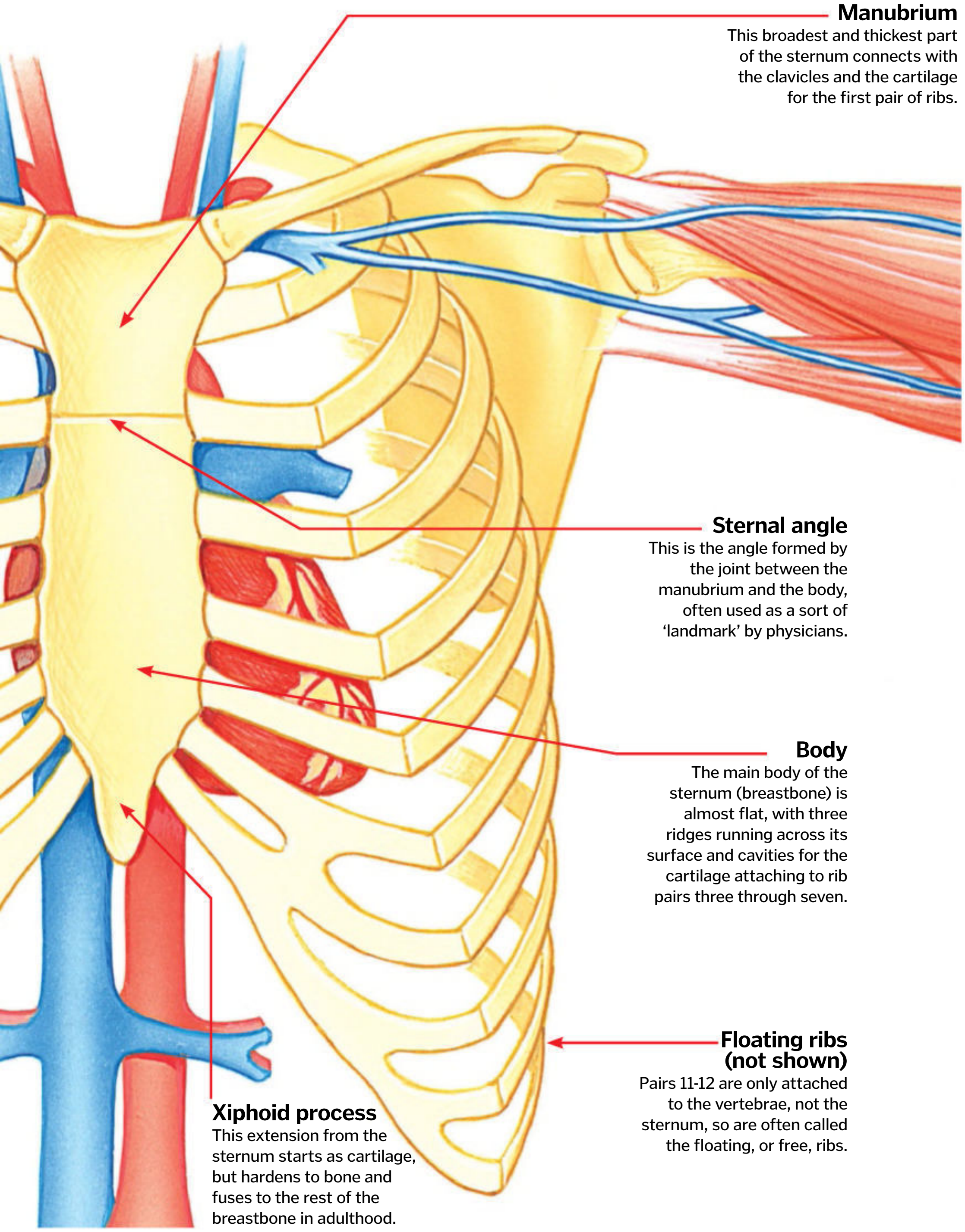
Rib fractures are a common and very painful injury, with the middle ribs the most likely ones to get broken. A fractured rib can be very dangerous, because a sharp piece could pierce the heart or lungs.

There's also a condition called flail chest, in which several ribs break and detach from the cage, which can even be fatal. But otherwise there's not much you can do to mend a fractured rib other than keep it stabilised, resting and giving it time to heal.

What are hiccups?

Hiccupping – known medically as singultus, or synchronous diaphragmatic flutter (SDF) – is an involuntary spasm of the diaphragm that can happen for a number of reasons. Short-term causes include eating or drinking too quickly, a sudden change in body temperature or shock.

However, some researchers have suggested that hiccupping in premature babies – who tend to hiccup much more than full-term babies – is due to their underdeveloped lungs. It could be an evolutionary leftover, since hiccupping in humans is similar to the way that amphibians gulp water and air into their gills to breathe.



Breathe in, breathe out…

Consciously take in a breath, and think about the fact that there are ten different muscle groups working together to make it happen. The muscles that move the ribcage itself are the intercostal muscles. They are each attached to the ribs and run between them. As you inhale, the external intercostals raise the ribs and sternum so your lungs can expand, while your diaphragm lowers and flattens. The internal intercostals lower the ribcage when you exhale. This forces the lungs to compress and release air (working in tandem with seven other muscles). If you breathe out gently, it's a passive process that doesn't require much ribcage movement.

Inhalation
As you inhale, the intercostal muscles contract to expand and lift the ribcage.

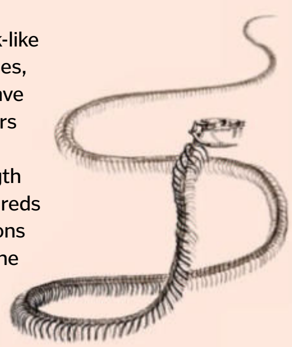
Contraction
The diaphragm contracts by moving downward, allowing the lungs to fill with air.

Exhalation
The intercostal muscles relax as we exhale, compressing and lowering the ribcage.

Relaxation
The diaphragm relaxes, moving upward to force air out of the lungs.

Ribs in other animals

Most vertebrates (ie animals with backbones) have a ribcage of sorts – however, ribcages can be very different depending on the creature. For example, dogs and cats have 13 pairs of ribs as opposed to our 12. Marsupials have fewer ribs than humans, and some of those are so tiny they aren't much more than knobs of bone sticking out from the vertebrae. Once you get into other vertebrates, the differences are even greater. Birds' ribs overlap one another with hook-like structures called uncinate processes, which add strength. Frogs don't have any ribs, while turtles' eight rib pairs are fused to the shell. A snake's 'ribcage', meanwhile, runs the length of its body and can comprise hundreds of pairs of ribs. Despite the variations in appearance, ribcages all serve the same basic functions for the most part: to provide support and protection to the rest of the body.



How the pancreas works

Learn how the workhorse of the digestive system helps to break down food and control our blood sugar levels

The pancreas is a pivotal organ within the digestive system. It sits inside the abdomen, behind the stomach and the large bowel, adjacent to the spleen. In humans, it has a head, neck, body and tail. It is connected to the first section of the small intestine, the duodenum, by the pancreatic duct, and to the bloodstream via a rich network of vessels. When it comes to the function of the pancreas, it is best to think about the two types of cell it contains: endocrine and exocrine.

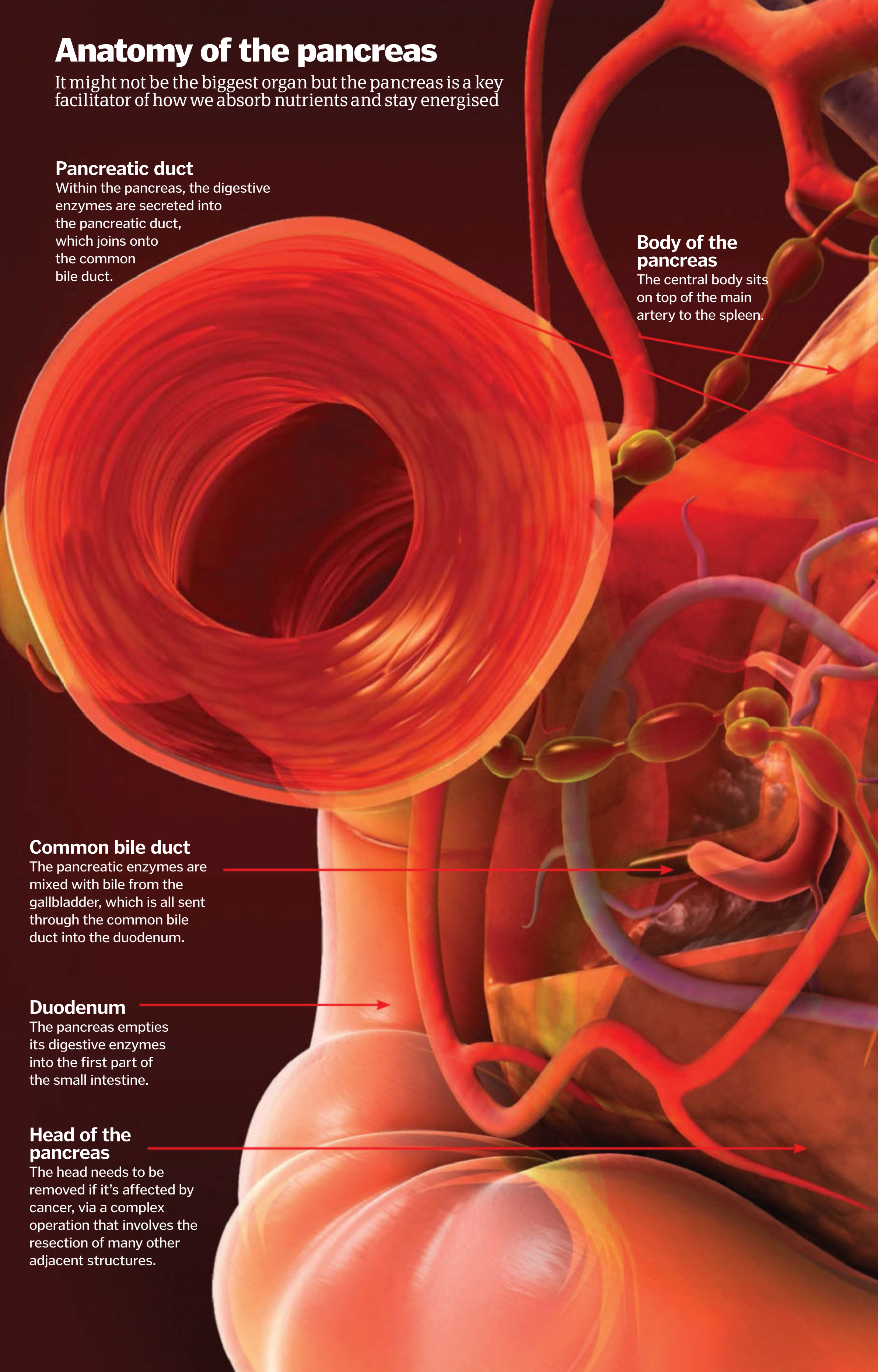
The endocrine pancreas is made up of clusters of cells called islets of Langerhans, which in total contain approximately 1 million cells and are responsible for producing hormones. These cells include alpha cells, which secrete glucagon, and beta cells which generate insulin. These two hormones have opposite effects on blood sugar levels throughout the body: glucagon increases glucose levels, while insulin decreases them.

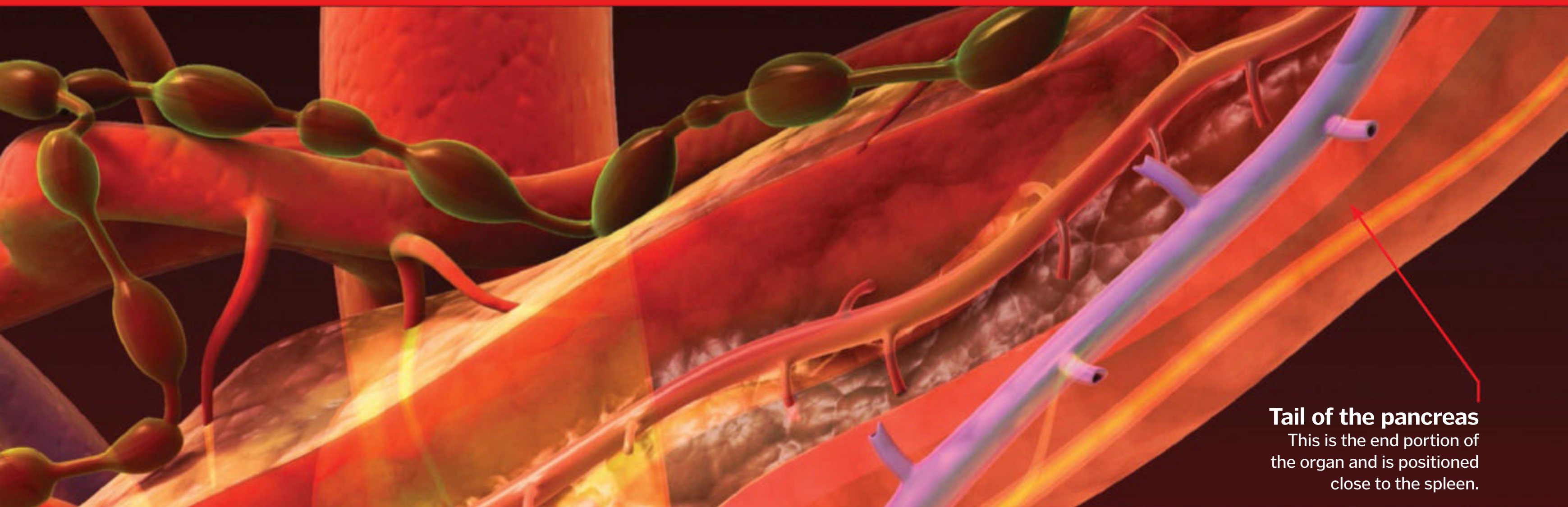
The cells here are all in contact with capillaries, so hormones which are produced can be fed directly into the bloodstream. Insulin secretion is under the control of a negative-feedback loop; high blood sugar leads to insulin secretion, which then lowers blood sugar with subsequent suppression of insulin. Disorders of these cells (and thus alterations of hormone levels) can lead to many conditions, including diabetes. The islets of Langerhans are also responsible for producing other hormones, like somatostatin, which governs nutrient absorption among other things.

The exocrine pancreas, meanwhile, is responsible for secreting digestive enzymes. Cells are arranged in clusters called acini, which flow into the central pancreatic duct. This leads into the duodenum – part of the small bowel – to come into contact with and aid in the digestion of food. The enzymes secreted include proteases (to digest protein), lipases (for fat) and amylase (for sugar/starch). Secretion of these enzymes is controlled by a series of hormones, which are released from the stomach and duodenum in response to the stretch from the presence of food.

Anatomy of the pancreas

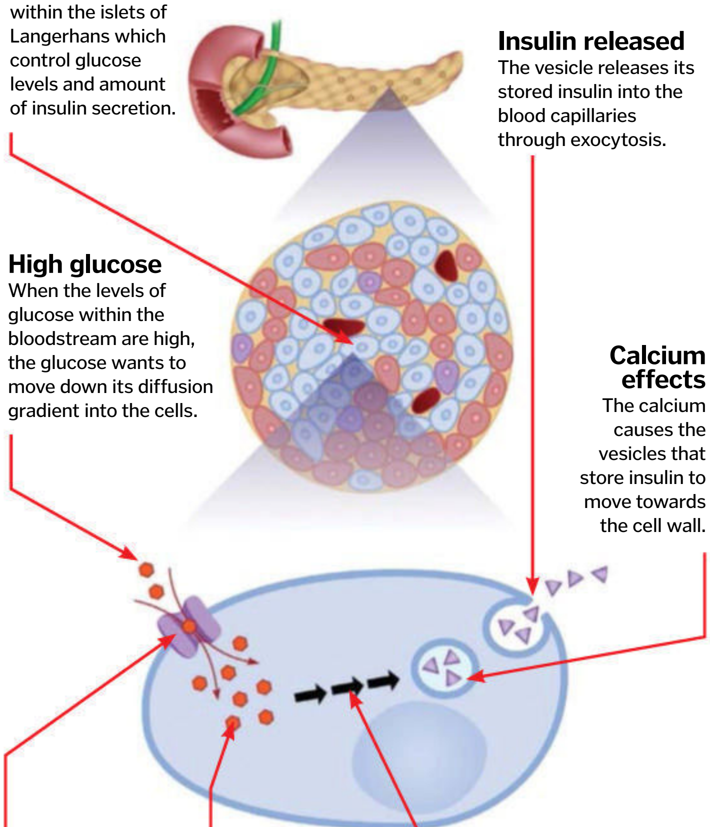
It might not be the biggest organ but the pancreas is a key facilitator of how we absorb nutrients and stay energised





What brings on diabetes?

Diabetes is a condition where a person has higher blood sugar than normal. It is either caused by a failure of the pancreas to produce insulin (ie type 1, or insulin-dependent diabetes mellitus), or resistance of the body's cells to insulin present in the circulation (ie type 2, or non-insulin-dependent diabetes mellitus). There are also other disorders of the pancreas. Inflammation of the organ (ie acute pancreatitis) causes severe pain in the upper abdomen, forcing most people to attend the emergency department as it can be life threatening. In contrast, cancer of the pancreas causes gradually worsening pain which can often be mistaken for other ailments.



Does the pancreas vary in humans and animals?

Every vertebrate animal has a pancreas of some form, meaning they are all susceptible to diabetes too. The arrangement, however, varies from creature to creature. In humans, the pancreas is most often a single structure that sits at the back of the abdomen. In other animals, the arrangement varies from two or three masses of tissue scattered around the abdomen, to tissue interspersed within the connective tissue between the bowels, to small collections of tissue within the bowel mucosal wall itself. One of the other key differences is the number of ducts that connect the pancreas to the bowel. In most humans there's only one duct, but occasionally there may be two or three – and sometimes even more. In other animals, the number is much more variable. However, the function is largely similar, where the pancreas secretes digestive enzymes and hormones to control blood sugar levels.

When you've got to go, you've got to go… but really our bodies are reacting to our bladders' direction

© Thinkstock

How your bladder works

As a key part of the urinary system, the bladder is crucial to removing waste from your body

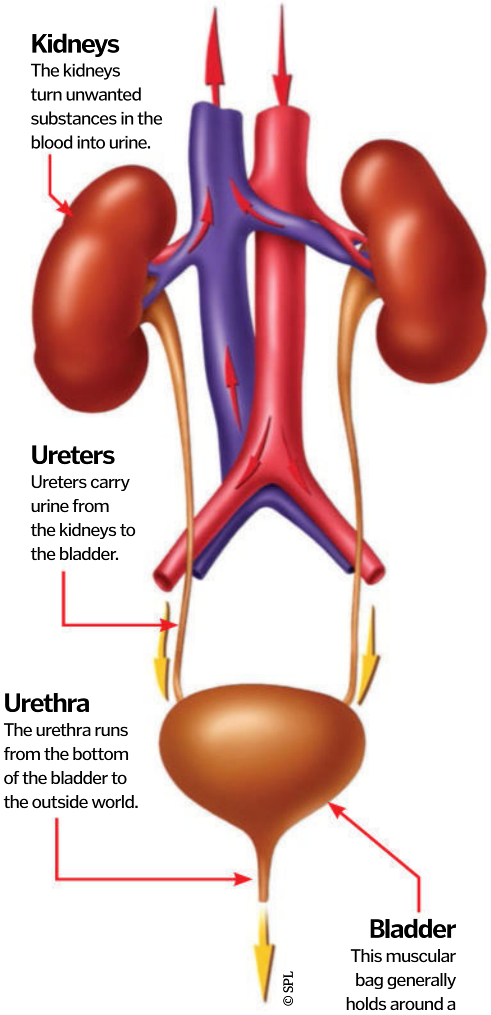
The bladder is one of the key organs in the urinary system and it stores urine following production by the kidneys until the body can release it.

Urine is a waste substance produced by the kidneys as they filter our blood of toxins and other unneeded elements. Up to 150 litres (40 gallons) of blood are filtered per day by your kidneys, but only around two litres (0.5 gallons) of waste actually pass down the ureters to the bladder.

Urine travels down the ureters and through the ureter valves, which attach each tube to the organ and prevent any liquid passing back. The bladder walls, controlled by the detrusor muscles, relax as urine enters and allow the organ to fill. When the bladder becomes full, or nearly full, the nerves in the bladder communicate with the brain, which in turn induces an urge to urinate. This sensation will get stronger if you do not go – creating the 'bursting for a wee' feeling that you can occasionally experience. When ready to urinate, both the internal and external sphincters relax and the detrusor muscles in the bladder wall contract in order to generate pressure, forcing urine to pass down the urethra and exit the body.

As well as telling you when you need to pass fluid, the urinary system also helps to maintain the mineral and salt balance in your body. For instance, when salts and minerals are too highly concentrated, you feel thirst to regain the balance.

THE COMPLETE URINARY SYSTEM



Kidneys
The kidneys turn unwanted substances in the blood into urine.

Ureters
Ureters carry urine from the kidneys to the bladder.

Urethra
The urethra runs from the bottom of the bladder to the outside world.

Bladder
This muscular bag generally holds around a pint of urine.

© SPL

Incontinence explained

For the bladder to work correctly, several areas within it must all function properly. It is most commonly the failure of one of these features that leads to incontinence.

A common type of urinary incontinence is urge incontinence. This is when an individual feels a sudden compulsion to urinate and will release urine without control. It is often caused by involuntary spasms by the detrusor muscles which can be a result of either nervous system problems or infections.

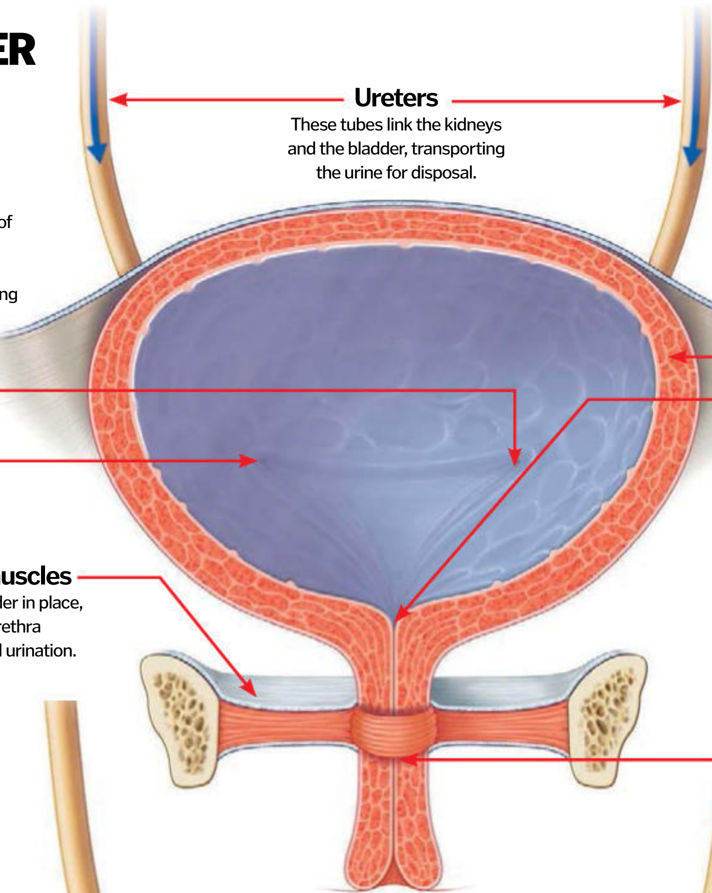
Another type is stress incontinence, caused when the external sphincter or pelvic floor muscles are damaged. This means urine can accidentally escape, especially if the pelvic floor is under pressure (eg while coughing, laughing or sneezing). This kind of incontinence is most common in the elderly.

One modern remedy is a preventative implant that has been developed to replace post-event incontinence pads. This comes in the form of a collagen-based substance injected around the urethra in order to support it.

Inside the bladder

How this organ acts as the middleman between your kidneys and excretion

FULL BLADDER



Ureters
These tubes link the kidneys and the bladder, transporting the urine for disposal.

Ureter valves
These sit at the end of the ureters and let urine pass into the bladder without letting it flow back.

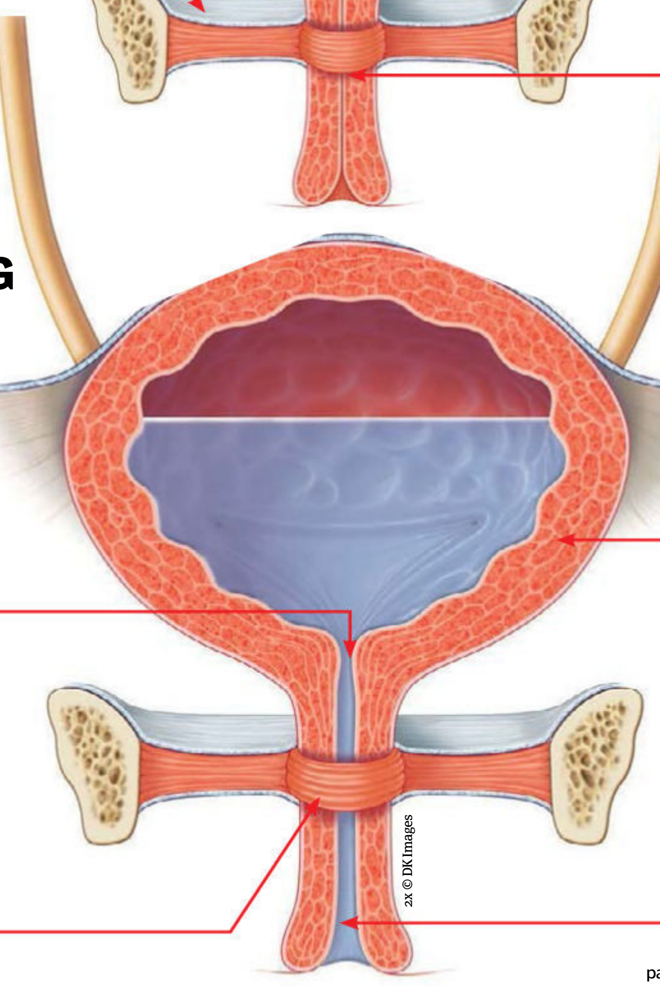
Bladder wall (detrusor muscles)
The detrusor muscles make up a layer of the bladder wall. These muscles cause the wall to relax and extend as urine enters, while nerves situated in the wall measure how full the bladder is and will signal to the brain when to urinate.

Internal urethral sphincter
The internal sphincter is controlled by the body. It stays closed to stop urine passing out of the body.

Pelvic floor muscles
These hold the bladder in place, and sit around the urethra stopping unintended urination.

External urethral sphincter (distal sphincter)
This sphincter is controlled by the individual, and they control whether to open or close the valve.

EMPTYING BLADDER



Bladder wall (controlled by detrusor muscles)
These muscles contract to force the urine out of the bladder.

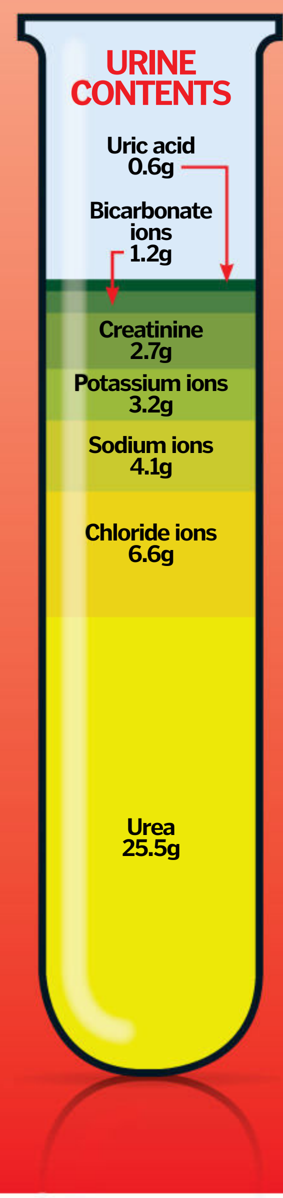
Internal urethral sphincter
This relaxes when the body is ready to expel the waste liquid.

External urethral sphincter (distal sphincter)
This also relaxes for the urine to exit the body.

Urethra
Urine travels down this passageway to leave the body.

What is urine made up of?

A human bladder usually holds around 350 millilitres (0.7 pints) of urine, though male bladders can typically hold slightly more than those of females. Urine is made up of urea, the waste by-product the body forms while breaking down protein across the body. The kidneys will filter this out and pass it with extra water to the bladder for expulsion. Other waste products produced or consumed by the body that pass through the kidneys will also exit the body via this route. Typically, urine is made up of 95 per cent water and 5 per cent dissolved or suspended solids including urea, plus chloride, sodium and potassium ions.



The urinary system explained

Every day the body produces waste products that enter the bloodstream – but how do we get rid of them?

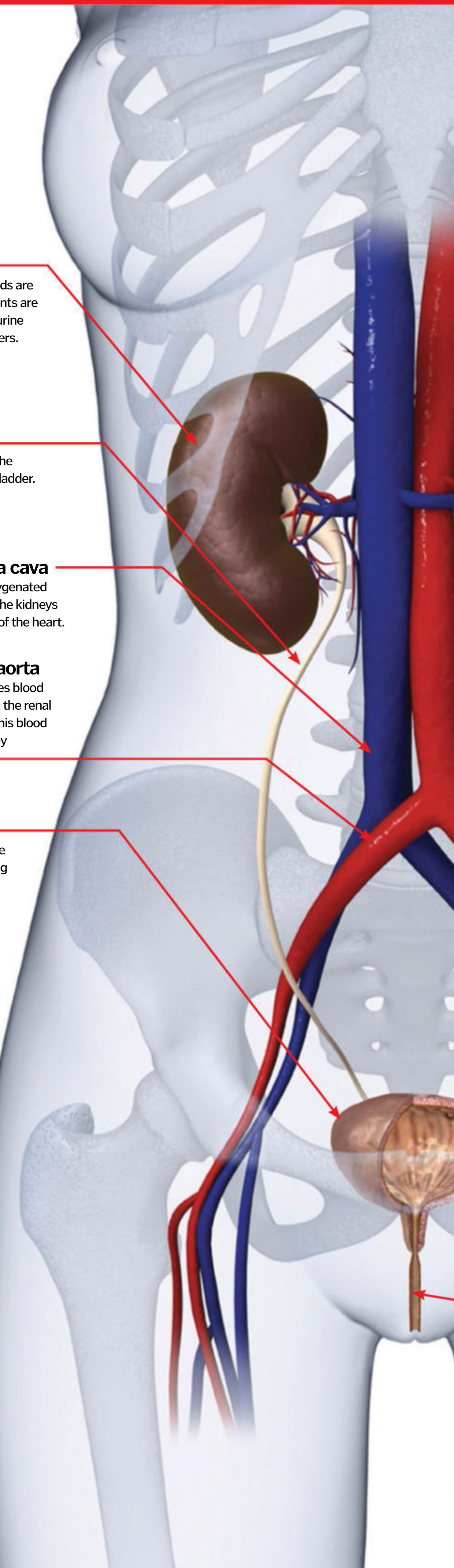
The human urinary system's primary function is to remove by-products which remain in the blood after the body has metabolised food. The process is made up of several different key features. Generally, this system consists of two kidneys, two ureters, the bladder, two sphincter muscles (one internal, one external) and a urethra and these work alongside the intestines, lungs and skin, all of which excrete waste products from the body.

The abdominal aorta is an important artery to the system as this feeds the renal artery and vein, which supply the kidneys with blood. This blood is filtered by the kidneys to remove waste products, such as urea which is formed through amino acid metabolism. Through communication with other areas of the body, such as the hypothalamus, the kidneys also control water levels in the body, sodium and potassium levels among other electrolytes, blood pressure, pH of the blood and are also involved in red blood cell production through the creation and release of the hormone erythropoietin. Consequently, they are absolutely crucial to optimum body operation.

After blood has been filtered by the kidneys, the waste products then travel down the ureters to the bladder. The bladder's walls expand out to hold the urine until the body can excrete the waste out through the urethra. The internal and external sphincters then control the release of urine.

Generally, a human will produce approximately 2.5-3 litres of urine a day, although this can vary dramatically dependant on external factors such as water consumption.

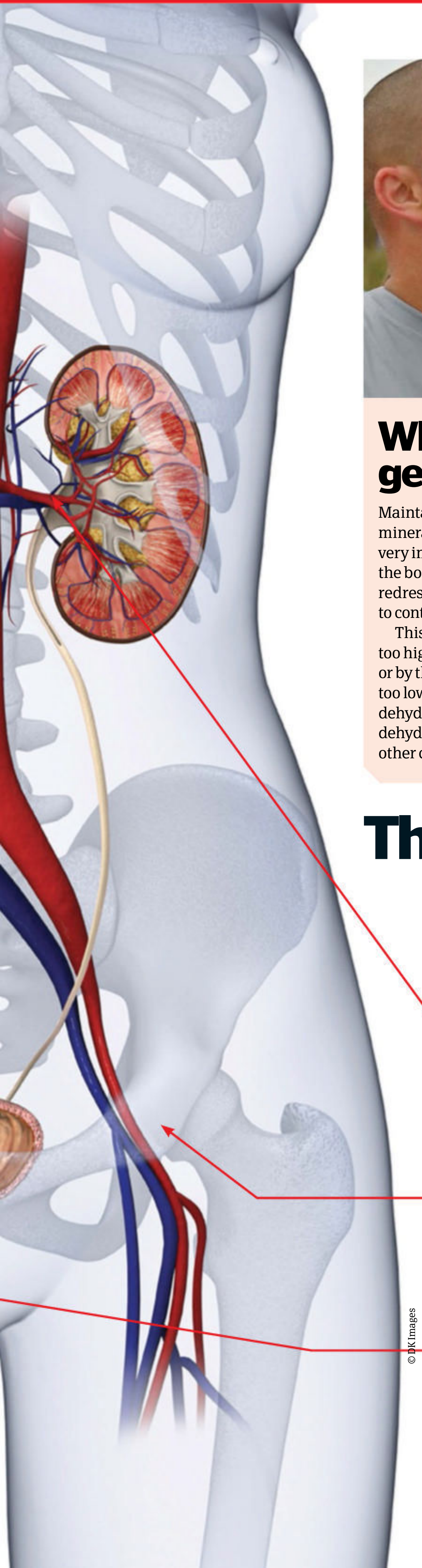
> "Generally, a human will produce 2.5-3 litres of urine a day"



How do the kidneys work?

The kidneys will have around 150-180 litres of blood to filter per day, but only pass around two litres of waste down the ureters to the bladder for excretion, therefore the kidneys return much of this blood, minus most of the waste products, to the heart for re-oxygenation and recirculation around the body.

The way the kidneys do this is to pass the blood through a small filtering unit called a nephron. Each kidney has around a million of these, which are made up of a number of small blood capillaries and a tube called the renal tubule. The blood capillaries sift the normal cells and proteins from the blood for recirculation and then direct the waste products into the renal tubule. This waste, which will primarily consist of urea, mixes with water and forms urine as it passes through the renal tubule and then into the ureter on its way to the bladder.



Why do we get thirsty?

Maintaining the balance between the minerals and salts in our body and water is very important. When this is out of balance, the body tells us to consume more liquids to redress this imbalance in order for the body to continue operating effectively.

This craving, or thirst, can be caused by too high a concentration of salts in the body, or by the water volume in the body dropping too low for optimal operation. Avoiding dehydration is important as long term dehydration can cause renal failure, among other conditions.

The human urinary system

Renal artery and vein
This supplies blood to the kidneys in order for them to operate, and then removes deoxygenated blood after use by the kidneys.

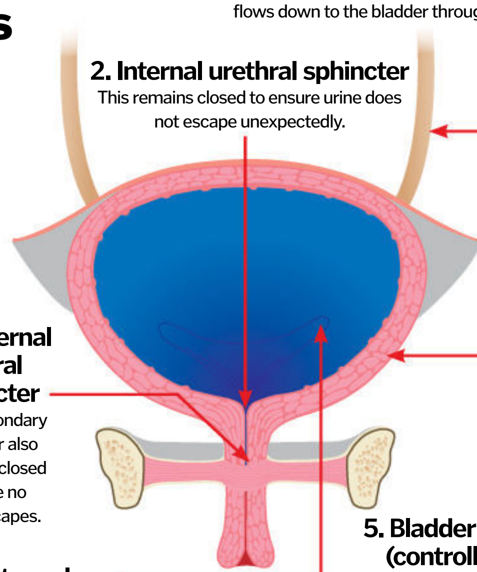
Pelvis
The bladder sits in the pelvis, and the urethra passes through it for urine to exit the body.

Urethra
The urethra is the tube that urine travels through to exit the body.

How do we store waste until we're ready to expel it?

The bladder stores waste products by allowing the urine to enter through the ureter valves, which attach the ureter to the bladder. The walls relax as urine enters and this allows the bladder to stretch. When the bladder becomes full, the nerves in the bladder communicate with the brain and cause the individual to feel the urge to urinate. The internal and external sphincters will then relax, allowing urine to pass down the urethra.

Bladder fills



1. Ureters
These tubes connect to the kidneys and urine flows down to the bladder through them.

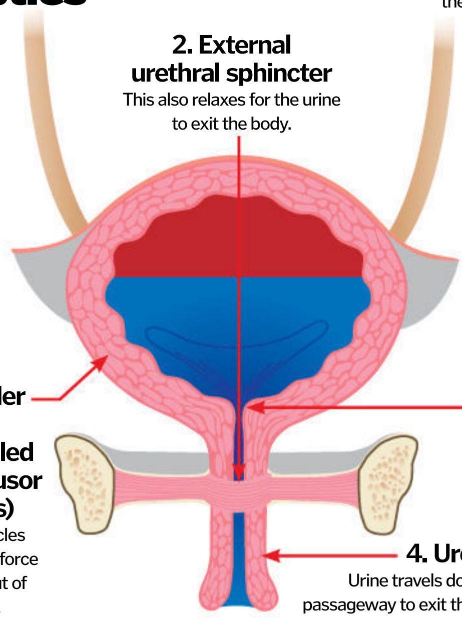
2. Internal urethral sphincter
This remains closed to ensure urine does not escape unexpectedly.

3. External urethral sphincter
This secondary sphincter also remains closed to ensure no urine escapes.

4. Ureter valves
These valves are situated at the end of the ureters and let urine in.

5. Bladder walls (controlled by detrusor muscles)
The detrusor muscles in the wall of the bladder relax to allow expansion of the bladder as necessary.

Bladder empties



1. Internal urethral sphincter
This relaxes when the body is ready to expel the waste.

2. External urethral sphincter
This also relaxes for the urine to exit the body.

3. Bladder walls (controlled by detrusor muscles)
These muscles contract to force the urine out of the bladder.

4. Urethra
Urine travels down this passageway to exit the body.

Inside the human stomach

Discover how this amazing digestive organ stretches, churns and holds corrosive acid to break down our food, all without getting damaged

The stomach's major role is as a reservoir for food; it allows large meals to be consumed in one sitting before being gradually emptied into the small intestine. A combination of acid, protein-digesting enzymes and vigorous churning action breaks the stomach contents down into an easier-to-process liquid form, preparing food for absorption in the bowels.

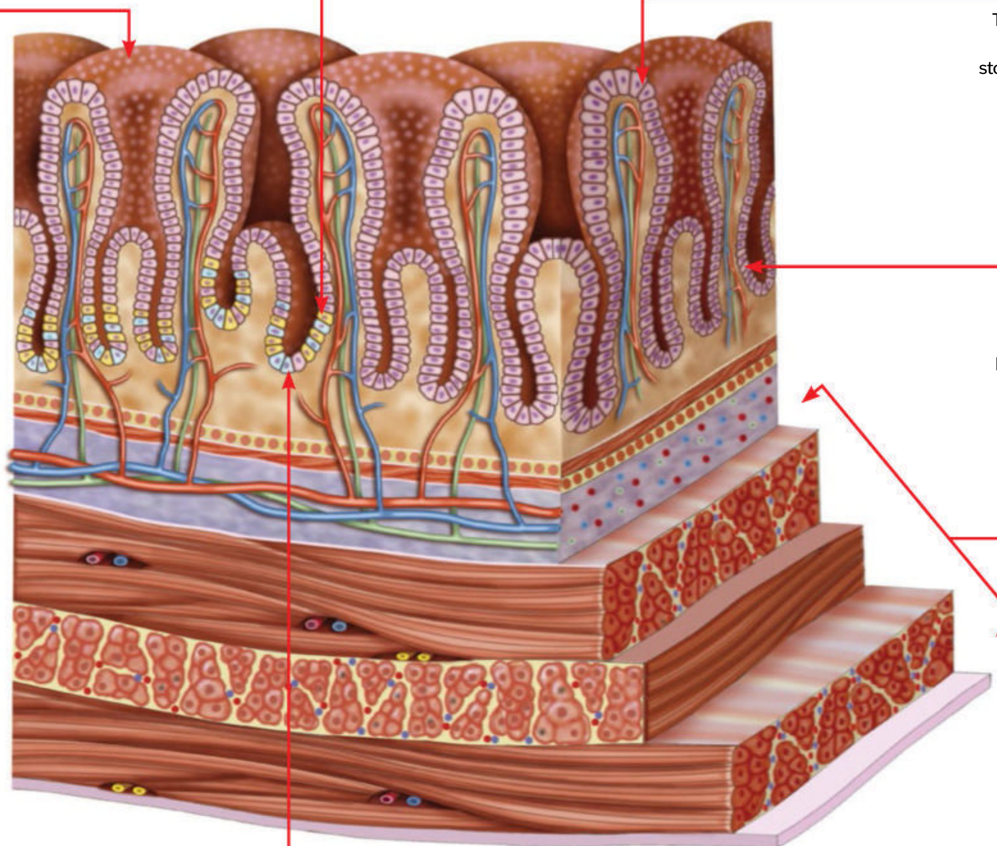
In its resting state, the stomach is contracted and the internal surface of the organ folds into characteristic ridges, or rugae. When we start eating, however, the stomach begins to distend; the rugae flatten, allowing the stomach to expand, and the outer muscles relax. The stomach can accommodate about a litre (1.8 pints) of food without discomfort.

The expansion of the stomach activates stretch receptors, which trigger nerve signalling that results in increased acid production and powerful muscle contractions to mix and churn the contents. Gastric acid causes proteins in the food to unravel, allowing access by the enzyme pepsin, which breaks down protein. The presence of partially digested proteins stimulates enteroendocrine cells (G-cells) to make the hormone gastrin, which encourages even more acid production.

The stomach empties its contents into the small intestine through the pyloric sphincter. Liquids pass through the sphincter easily, but solids must be smaller than one to two millimetres (0.04-0.08 inches) in diameter before they will fit. Anything larger is 'refluxed' backwards into the main chamber for further churning and enzymatic breakdown. It takes about two hours for half a meal to pass into the small intestine and the process is generally complete within four to five hours.

Lining under the microscope

The stomach is much more than just a storage bag. Take a look at its complex microanatomy now…



Chief cell (yellow)
Chief cells make pepsinogen; at the low pH in the stomach it becomes the digestive enzyme pepsin, which deconstructs protein.

Gastric pits
The entire surface of the stomach is covered in tiny holes, which lead to the glands that produce mucus, acid and enzymes.

Mucous cell
These cells secrete alkaline mucus to protect the stomach lining from damage by stomach acid.

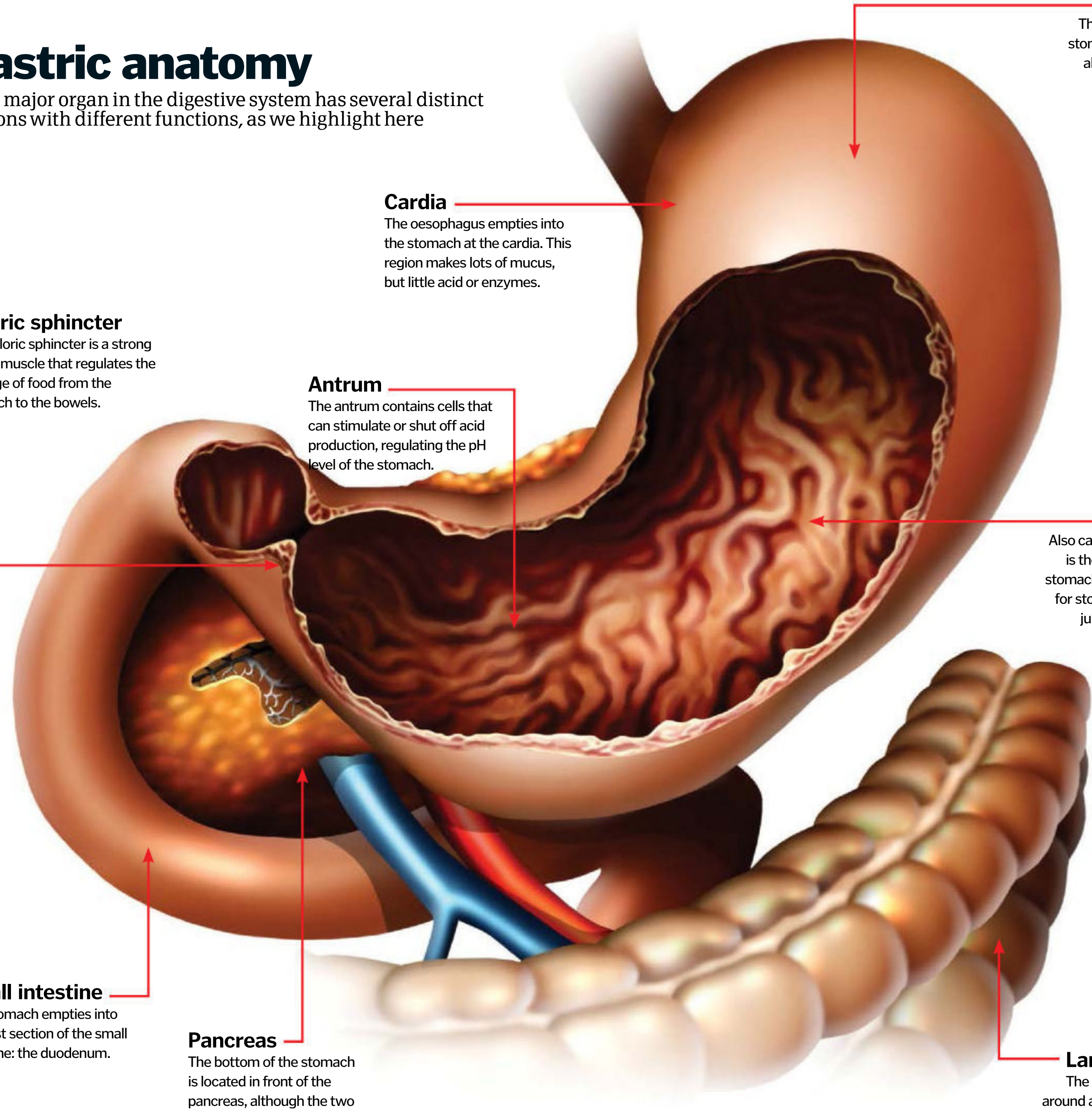
G-cell (pink)
Also known as enteroendocrine cells, these produce hormones like gastrin, which regulate acid production and stomach contraction.

Parietal cell (blue)
These cells produce hydrochloric acid, which kills off micro-organisms, unravels proteins and activates digestive enzymes.

Muscle layers
The stomach has three layers of muscle running in different orientations. These produce the co-ordinated contraction required to mix food.

Gastric anatomy

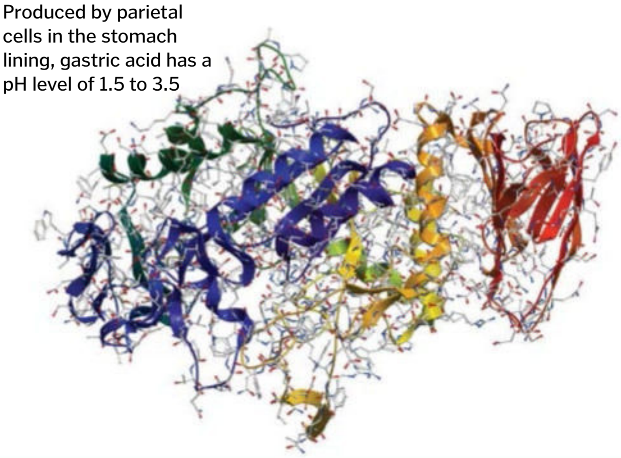
This major organ in the digestive system has several distinct regions with different functions, as we highlight here



Why doesn't it digest itself?

Your stomach is full of corrosive acid and enzymes capable of breaking down protein – if left unprotected the stomach lining would quickly be destroyed. To prevent this from occurring, the cells lining the stomach wall produce carbohydrate-rich mucus, which forms a slippery, gel-like barrier. The mucus contains bicarbonate, which is alkaline and buffers the pH at the surface of the stomach lining, preventing damage by acid. For added protection, the protein-digesting enzyme pepsin is created from a zymogen (the enzyme in its inactive form) – pepsinogen; it only becomes active when it comes into contact with acid, a safe distance away from the cells that manufacture it.

Produced by parietal cells in the stomach lining, gastric acid has a pH level of 1.5 to 3.5



Vomit reflex step-by-step

Vomiting is the forceful expulsion of the stomach contents up the oesophagus and out of the mouth. It's the result of three co-ordinated stages. First, a deep breath is drawn and the body closes the glottis, covering the entrance to the lungs. The diaphragm then contracts, lowering pressure in the thorax to open up the oesophagus. At the same time, the muscles of the abdominal wall contract, which squeezes the stomach. The combined shifts in pressure both inside and outside the stomach forces any contents upwards.

The human hand

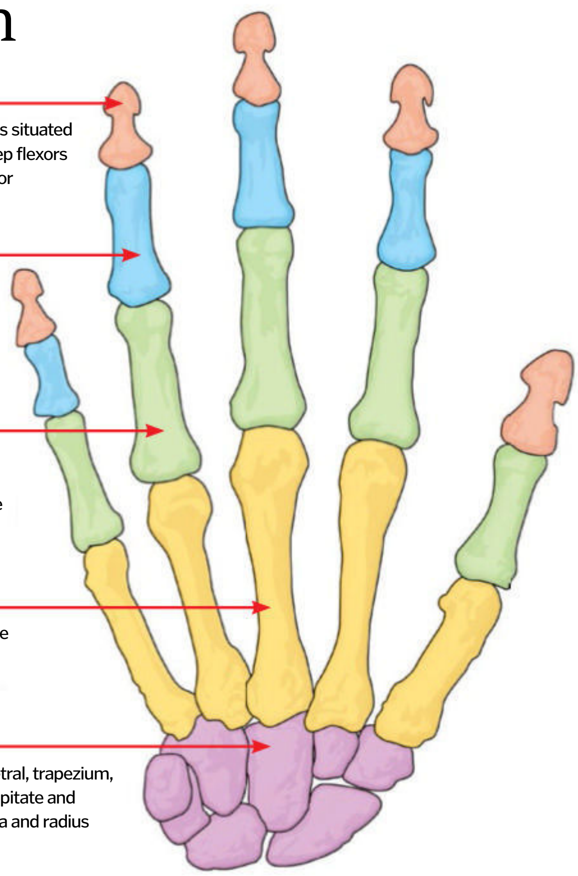
We take our hands for granted, but they are actually quite complex and have been crucial in our evolution

The human hand is an important feature of the human body, which allows individuals to manipulate their surroundings and also to gather large amounts of data from the environment that the individual is situated within. A hand is generally defined as the terminal aspect of the human arm, which consists of prehensile digits, an opposable thumb, and a wrist and palm. Although many other animals have similar structures, only primates and a limited number of other vertebrates can be said to have a 'hand' due to the need for an opposable thumb to be present and the degree of extra articulation that the human hand can achieve. Due to this extra articulation, humans have developed fine motor skills allowing for much increased control in this limb. Consequently we see improved ability to grasp and grip items and development of skills such as writing.

A normal human hand is made up of five digits, the palm and wrist. It consists of 27 bones, tendons, muscles and nerves, with each fingertip of each digit containing numerous nerve endings making the hand a crucial area for gathering information from the environment using one of man's most crucial five senses: touch. Muscles interact together with tendons to allow fingers to bend, straighten, point and, in the case of the thumb, rotate. However, the hand is an area that sees many injuries due to the number of ways we use it, one in ten injuries in A&E being hand related, and there are also several disorders that can affect the hand development in the womb, such as polydactyly, where an individual is born with extra digits, which are often in perfect working order.

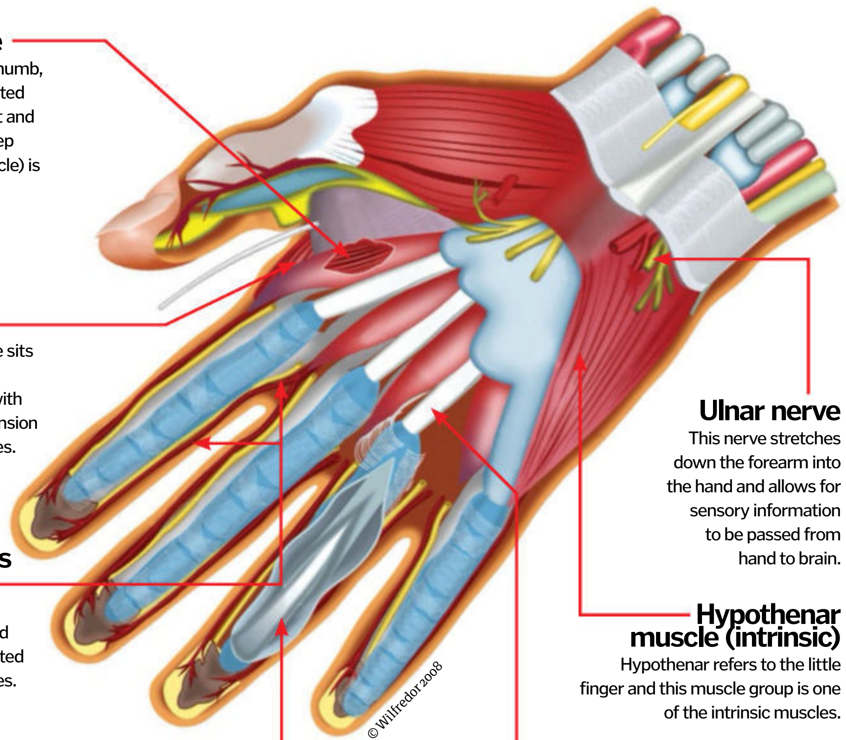
Bones in the hand

The human hand contains 27 bones, and these divide up into three distinct groups: the carpals, metacarpals and phalanges. These also then further break down into three: the proximal phalanges, intermediate phalanges and distal phalanges. Eight bones are situated in the wrist and these are collectively called the carpals. The metacarpals, which are situated in the palm of the hand account for a further five out of the 27, and each finger has three phalanges, the thumb has two. Intrinsic muscles and tendons interact to control movement of the digits and hand, and attach to extrinsic muscles that extend further up into the arm, which flex the digits.



Muscles and other structures

The movements and articulations of the hand and by the digits are controlled by tendons and two muscle groups situated within the hand and wrist. These are the extrinsic and intrinsic muscle groups, so named as the extrinsics are attached to muscles which extend into the forearm, whereas the intrinsics are situated within the hand and wrist. The flexors and extensors, which make up the extrinsic muscles, use either exclusively tendons to attach to digits they control (flexors) or a more complex mix of tendons and intrinsic muscles to operate (extensors). These muscles will contract in order to cause digit movement, and flexors and extensors work in a pair to complement each to straighten and bend digits. The intrinsic muscles are responsible for aiding extrinsic muscle action and other movements in the digits and have three distinct groups; the thenar and hypothenar (referring to the thumb and little finger respectively), the interossei and the lumbrical.



Thenar space
Thenar refers to the thumb, and this space is situated between the first digit and thumb. One of the deep flexors (extrinsic muscle) is located in here.

Interossei muscle (intrinsic)
This interossei muscle sits between metacarpal bones and will unite with tendons to allow extension using extrinsic muscles.

Arteries, veins and nerves
These supply fresh oxygenated blood (and take away deoxygenated blood) to hand muscles.

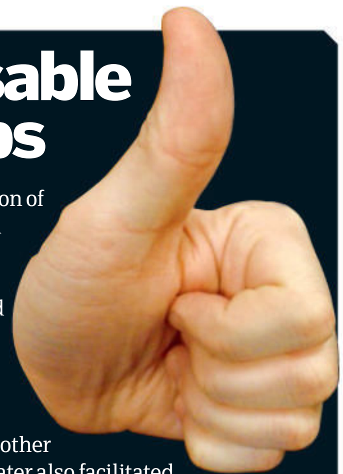
Insertion of flexor tendon
This is where the tendon attaches the flexor muscle to the finger bones to allow articulation.

Ulnar nerve
This nerve stretches down the forearm into the hand and allows for sensory information to be passed from hand to brain.

Hypothenar muscle (intrinsic)
Hypothenar refers to the little finger and this muscle group is one of the intrinsic muscles.

Mid palmar space
Tendons and intrinsic muscles primarily inhabit this space within the hand.

Opposable thumbs



Increased articulation of the thumb has been heralded as a key factor in human evolution. It allowed for increased grip and control, and for tool use to develop among human ancestors as well as other primates. This has later also facilitated major cultural advances, such as writing. Alongside the four other flexible digits, the opposable thumb makes the human hand one of the most dexterous in the world. A thumb can only be classified as opposable when it can be brought opposite to the other digits.

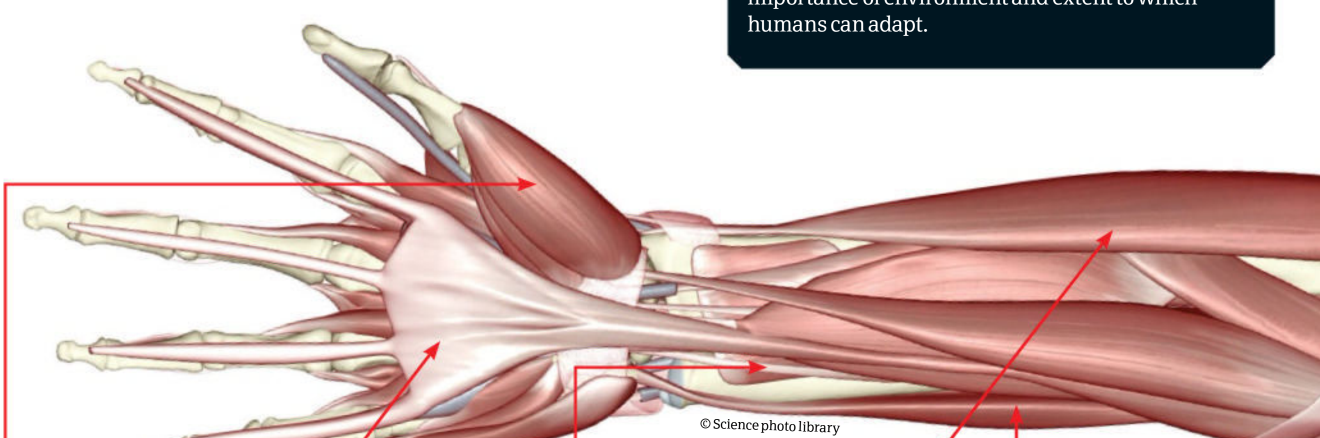
Left handed or right handed?

The most common theory for why some individuals are left handed is that of the 'disappearing twin'. This supposes that the left-handed individual was actually one of a set of twins, but that in the early stages of development the other, right handed, twin died. However, it's been found that dominance of one hand is directly linked with hemisphere dominance in the brain, as in many other paired organs.

Individuals who somehow damage their dominant hand for extended periods of time can actually change to use the other hand, proving the impact and importance of environment and extent to which humans can adapt.

Forearm muscles

Extrinsic muscles are so called because they are primarily situated outside the hand, the body of the muscles situated along the underside or front of the forearm. This body of muscles actually breaks down into two quite distinct groups: the flexors and the extensors. The flexors run alongside the underside of the arm and allow for the bending of the digits, whereas the extensor muscles' main purpose is the reverse this action, to straighten the digits. There are both deep and superficial flexors and extensors, and which are used at any one time depends on the digit to be moved.



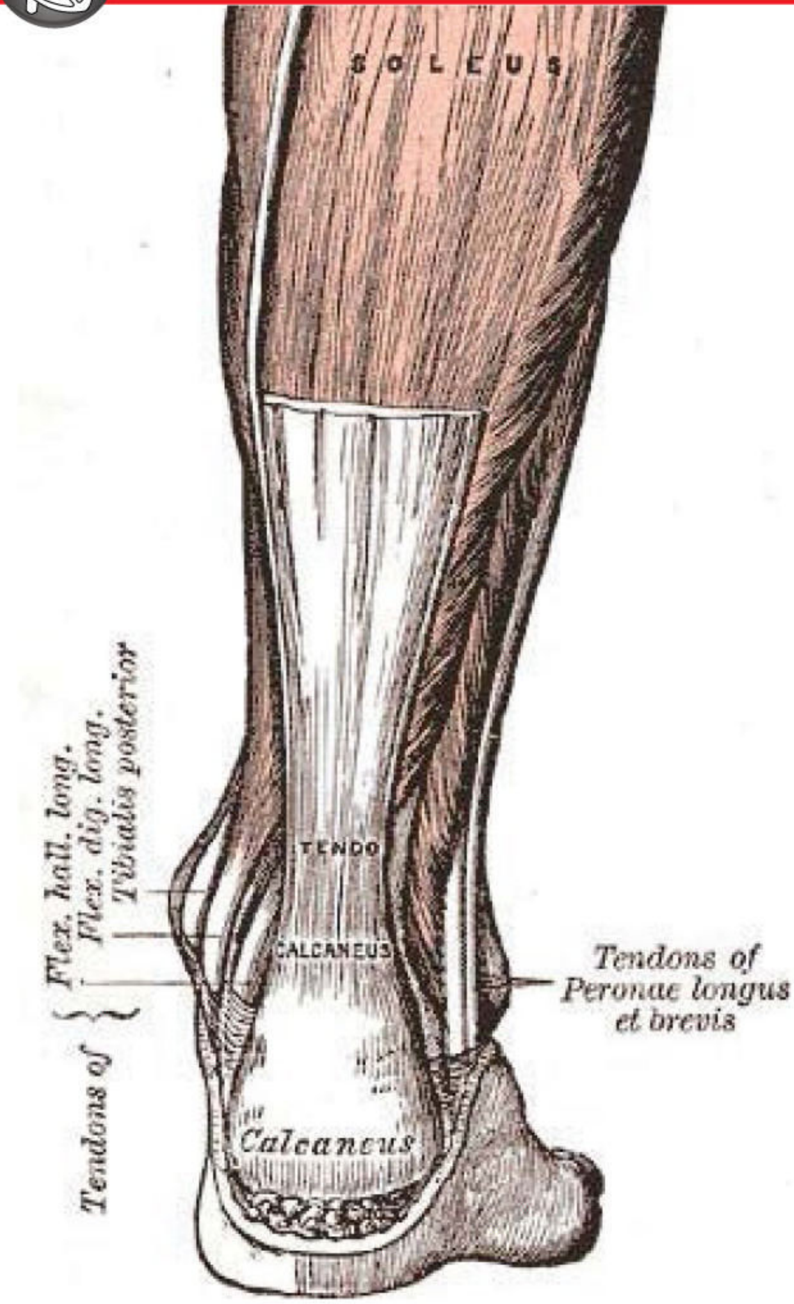
Tendons and intrinsics
These attach the flexor muscles to the phalanges, and facilitate bending. Tendons also interact with the intrinsics and extensors in the wrist, palm and forearm to straighten the digits.

Thenars
The intrinsic group of muscles is used to flex the thumb and control its sideways movement.

Superficial flexors
The other flexor that acts on the digits is the superior flexor, which attaches to the intermediate phalanges.

Deep flexors
The digits have two extrinsic flexors that allow them to bend, the deep flexor and the superficial. The deep flexor attaches to the distal phalanges.

Extensors
Extensors on the back of the forearm straighten the digits. Divided into six sections, their connection to the digits is complex.



What does the Achilles' tendon do?

Is it really a weak spot and how important is it?

This tendon, the strongest in your body, connects the calf muscles to the heel. When everything is fine, it pulls the back of the foot up when the calf muscles contract. This way, your heel raises and your weight goes to your toes.

It enables us to do such things as sprinting, hopping or jumping. It also stores elastic energy to do these tasks more efficiently. Biological anthropologists believe all this was very important for the way we evolved to run around on two legs and survive.

The Achilles' tendon is seemingly named thus after the mythological Greek character of Achilles, who during the Trojan War - made famous by Homer's epic poem *The Illiad* - is shot by a poisoned arrow in his unprotected heel - hence the common phrase describing a person's weak point.

What are our fingernails made of?

And how are they formed?

Fingernails are made of a tough protein called keratin (from the Greek word 'Kera', meaning horn). Keratin is also what animals hooves and horns are made from. Most animals have a supportive bone structure in their horns, although rhinoceros horns are made completely of keratin compacted together. The only other biological material which has a similar toughness to keratinised tissue is chitin, the main component of exoskeletons belonging to arthropods. The half-moon shape that you can see at the bottom of your nail (apart from maybe your little finger) is called the lanula. This is a group of cells that produce keratin and other living cells. As these living cells are pushed forward by newer cells, they die and merge with the keratin to become keritinised. They then become flattened, stiff and known as your fingernails.

"The half-moon shape that you can see at the bottom of your nail is called the lanula"

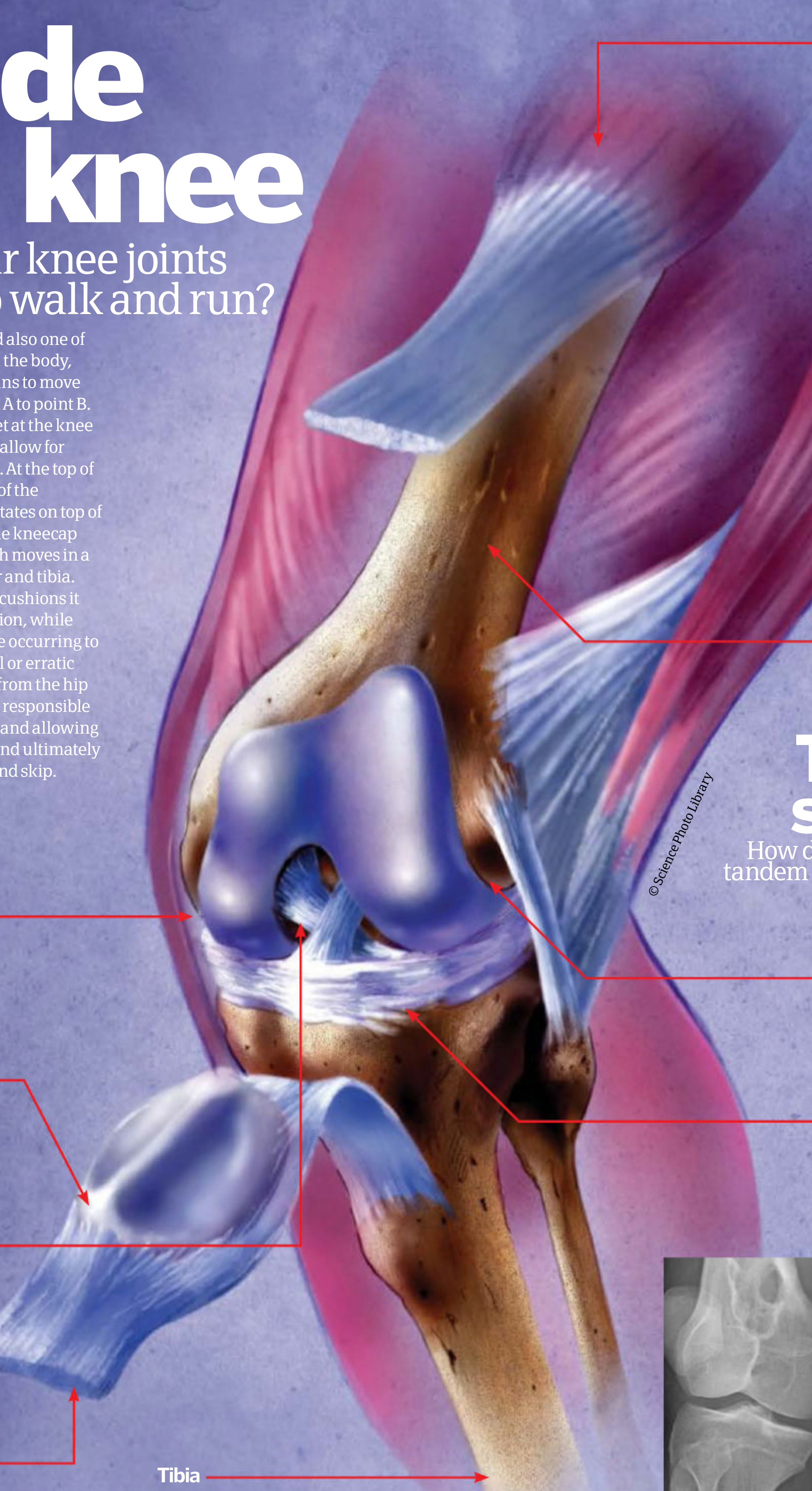
Inside the knee

How do our knee joints allow us to walk and run?

The knee is the largest and also one of the most complex joints in the body, allowing us bipedal humans to move around and get from point A to point B. Three different bones meet at the knee joint and work together to allow for movement and protection. At the top of the knee is the lower part of the thighbone (femur). This rotates on top of the shinbone (tibia) and the kneecap (patella), the latter of which moves in a groove between the femur and tibia. Cartilage within the knee cushions it from shock caused by motion, while ligaments prevent damage occurring to the joint in case of unusual or erratic motion. Muscles running from the hip down to the knee joint are responsible for working the knee joint and allowing our legs to bend, stretch, and ultimately allowing us to walk, run and skip.

The knee structure

How does everything work in tandem to allow for movement?



The patella, seen separated above, is also known as the kneecap

How do your feet work?

Feet are immensely complex structures, yet we put huge amounts of pressure on them every day. How do they cope?

The human foot and ankle is crucial for locomotion and is one of the most complex structures of the human body. This intricate structure is made up of no less than 26 bones, 20 muscles, 33 joints – although only 20 are articulated – as well as numerous tendons and ligaments. Tendons connect the muscles to the bones and facilitate movement of the foot, while ligaments hold the tendons in place and help the foot move up and down to initiate walking. Arches in the foot are formed by ligaments, muscles and foot bones and help to distribute weight, as well as making it easier for the foot to operate efficiently when walking and running. It is due to the unique structure of the foot and the way it distributes pressure throughout all aspects that it can withstand constant pressure throughout the day.

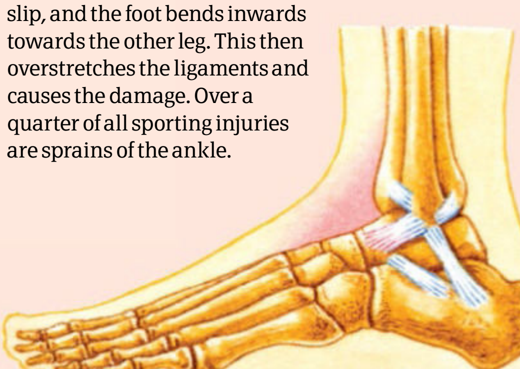
One of the other crucial functions of the foot is to aid balance, and toes are a crucial aspect of this. The big toe in particular helps in this area, as we can grip the ground with it if we feel we are losing balance.

The skin, nerves and blood vessels make up the rest of the foot, helping to hold the shape and also supplying it with all the necessary minerals, oxygen and energy to help keep it moving easily and constantly.

What happens when you sprain your ankle?

A sprained ankle is the most common type of soft tissue injury. The severity of the sprain can depend on how you sprained the ankle, and a minor sprain will generally consist of a stretched or only partially torn ligament. However, more severe sprains can cause the ligament to tear completely, or even force a piece of bone to break off.

Generally a sprain happens when you lose balance or slip, and the foot bends inwards towards the other leg. This then overstretches the ligaments and causes the damage. Over a quarter of all sporting injuries are sprains of the ankle.



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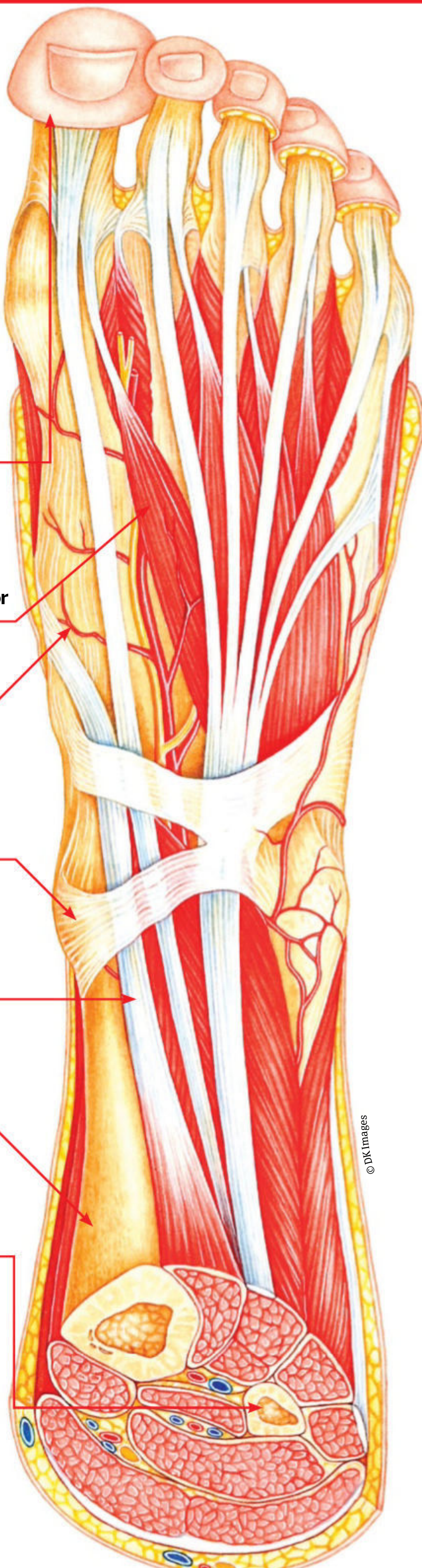
The structure of the foot and how the elements work together



Toes
Terminal aspects of the foot that aid balance by grasping onto the ground. They are the equivalent of fingers in the foot structure.

Muscles – including the extensor digitorum brevis muscle
Muscles within the foot help the foot lift and articulate as necessary. The extensor digitorum brevis muscle sits on the top of the foot, and helps flex digits two-four on the foot.

Blood vessels
These supply blood to the foot, facilitating muscle operation by supplying energy and oxygen and removing deoxygenated blood.

Ligaments
Ligaments support the tendons and help to form the arches of the foot, spreading weight across it.

Tendons (extensor digitorum longus, among others)
Fibrous bands of tissue which connect muscles to bones. They can withstand a lot of tension and link various aspects of the foot, facilitating movement.

Tibia
The larger and stronger of the lower leg bones, this links the knee and the ankle bones of the foot.

Fibula
This bone sits alongside the tibia, also linking the knee and the ankle.

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The structure of the foot enables us to stay balanced

How do we walk?

'Human gait' is the term to describe how we walk. This gait will vary between each person, but the basics are the same

1. Heel lift
The first step of walking is for the foot to be lifted off the ground. The knee will raise and the calf muscle and Achilles tendon, situated on the back of the leg, will contract to allow the heel to lift off the ground.

2. Weight transfer
The weight will transfer fully to the foot still in contact with the ground, normally with a slight leaning movement of the body.

3. Foot lift
After weight has transferred and the individual feels balanced, the ball of the first foot will then lift off the ground, raising the thigh.

4. Leg swing
The lower leg will then swing at the knee, under the body, to be placed in front of the stationary, weight- bearing foot.

5. Heel placement
The heel will normally be the part of the foot that's placed first, and weight will start to transfer back onto this foot as it hits the ground.

6. Repeat process
The process is then repeated with the other foot. During normal walking or running, one foot will start to lift as the other starts to come into contact with the ground.

Bones of the foot

A baby is born with 22 out of a total 26 bones in each foot

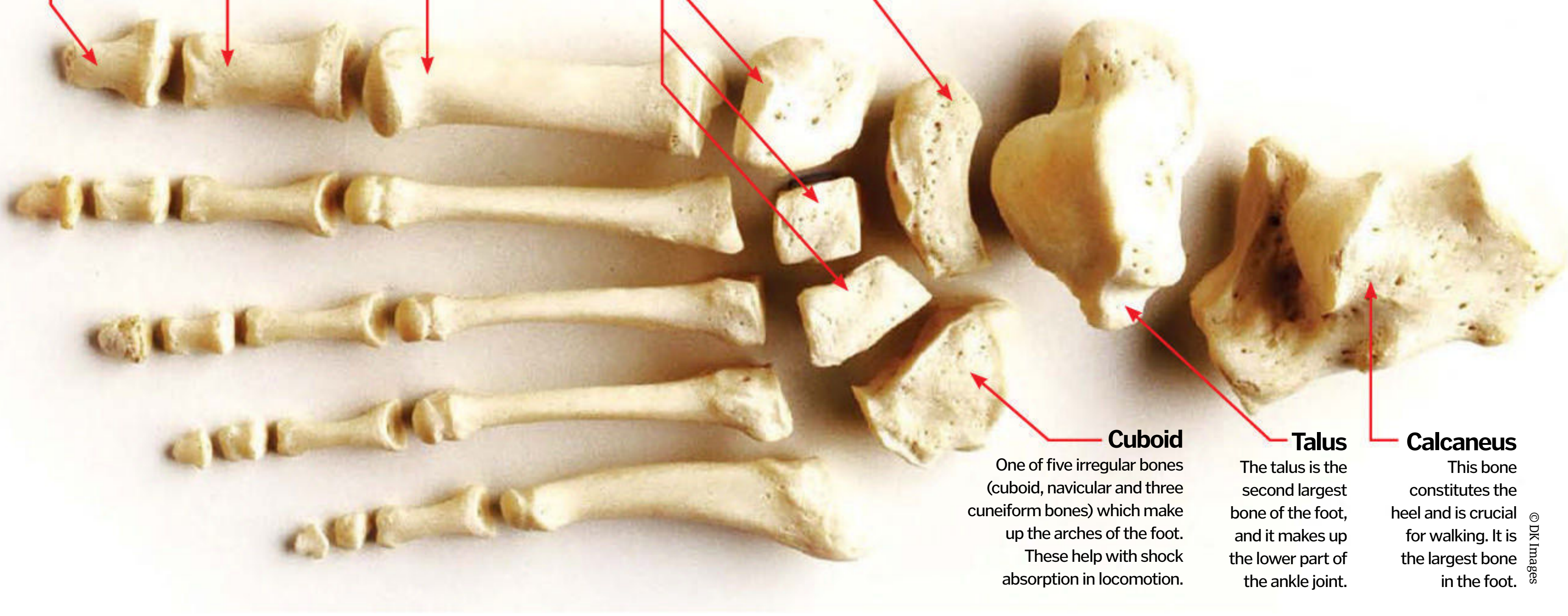
Distal phalanges
The bones which sit at the far end of the foot and make up the tips of the toes.

Proximal phalanges
These bones link the metatarsals and the distal phalanges and stretch from the base of the toes.

Metatarsals
The five, long bones that are the metatarsals are located between the tarsal bones and the phalanges. These are the equivalent of the metacarpals in the hand.

Cuneiforms bones (three)
Three bones that fuse together during bone development and sit between the metatarsals and the talus.

Navicular
This bone, which is so named due to its resemblance to a boat, articulates with the three cuneiform bones.

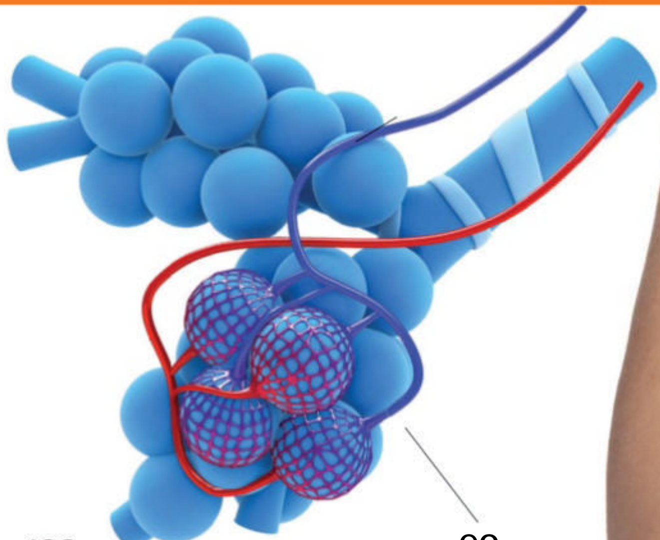


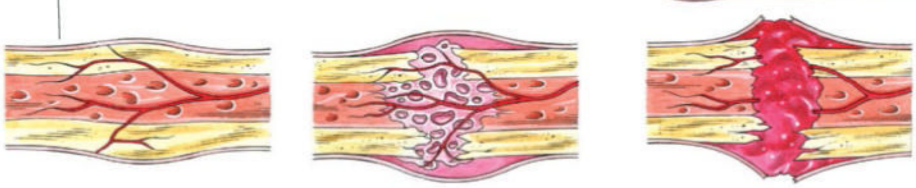
Cuboid
One of five irregular bones (cuboid, navicular and three cuneiform bones) which make up the arches of the foot. These help with shock absorption in locomotion.

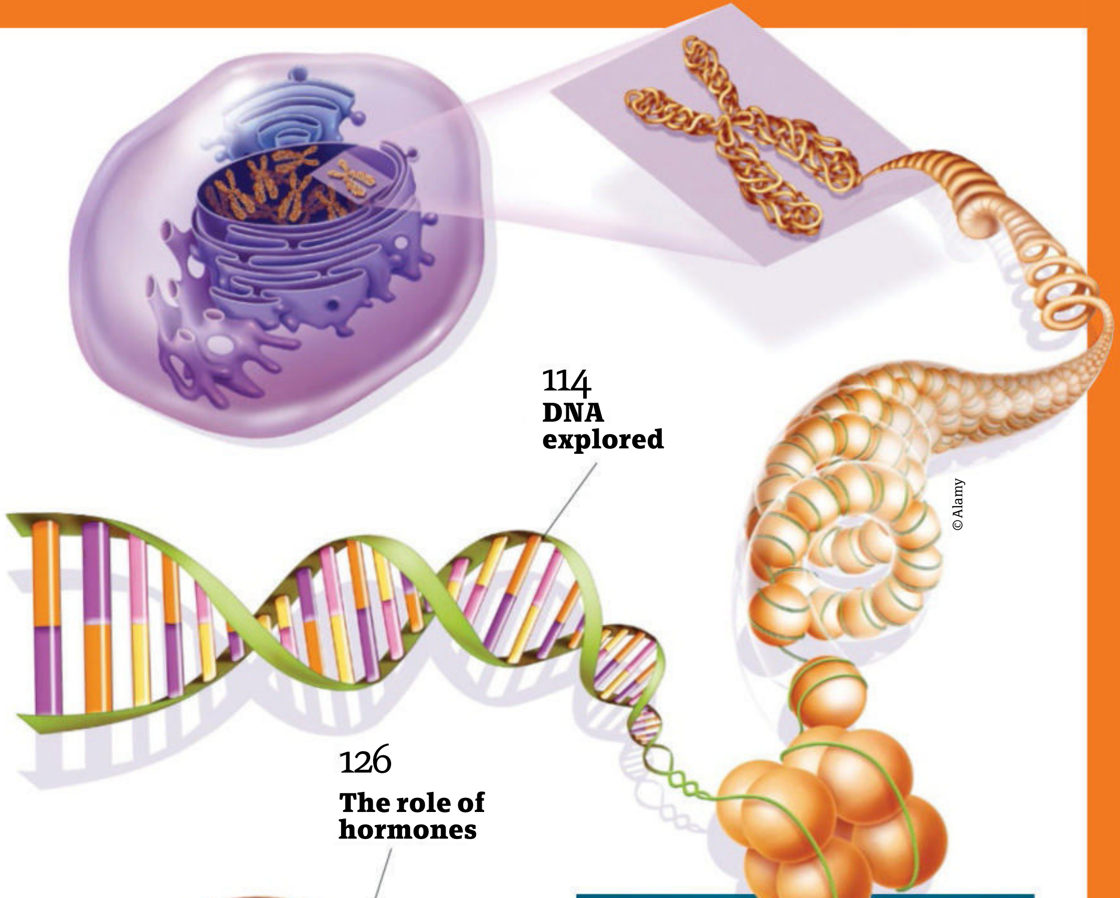
Talus
The talus is the second largest bone of the foot, and it makes up the lower part of the ankle joint.

Calcaneus
This bone constitutes the heel and is crucial for walking. It is the largest bone in the foot.

THE BODY AT WORK







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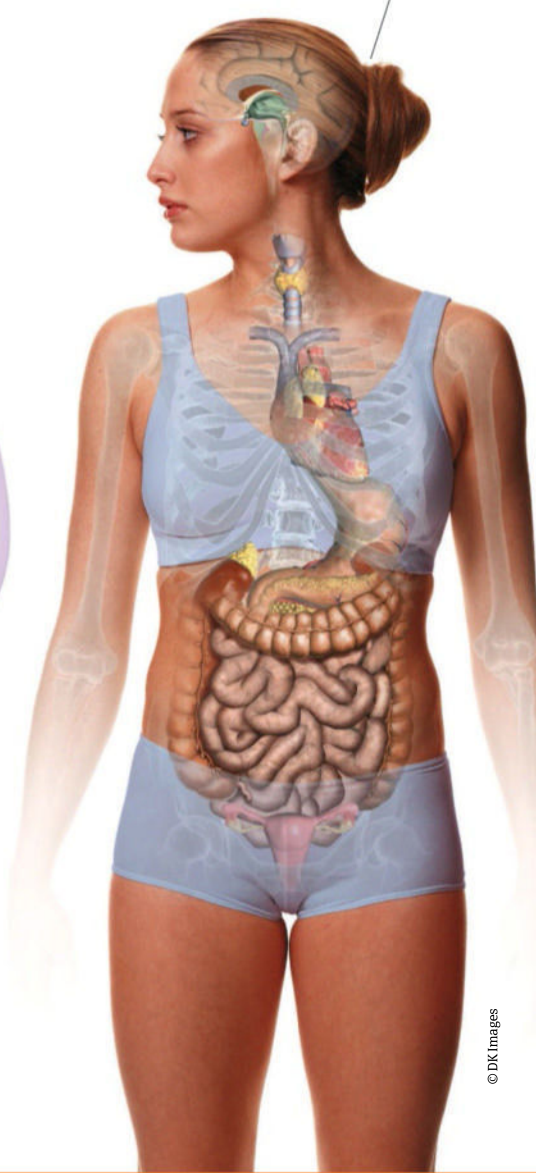

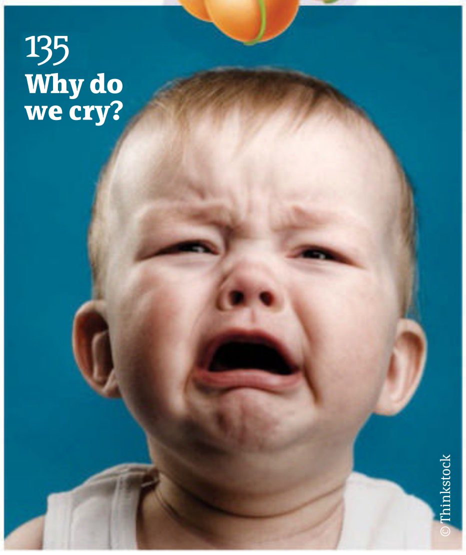

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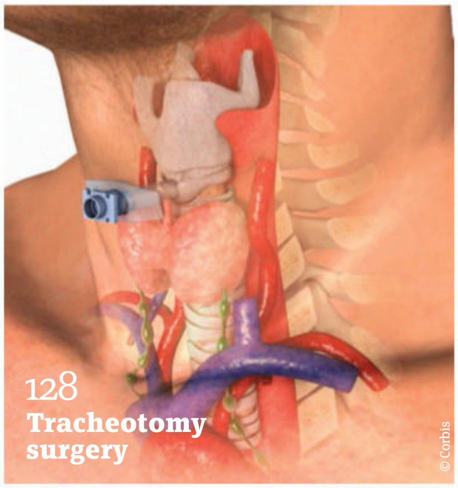
Why do we cry?



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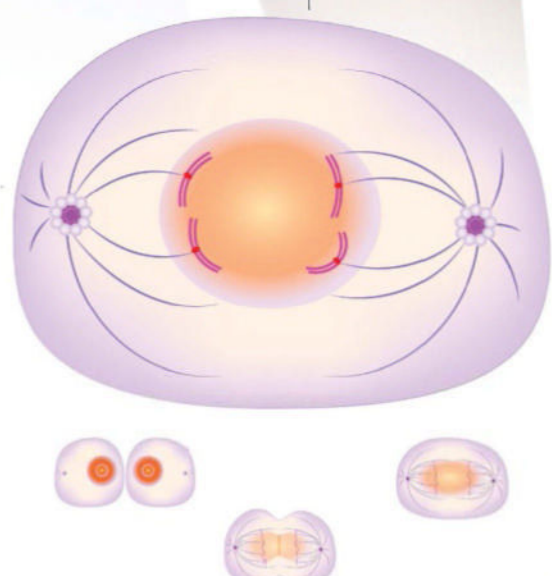
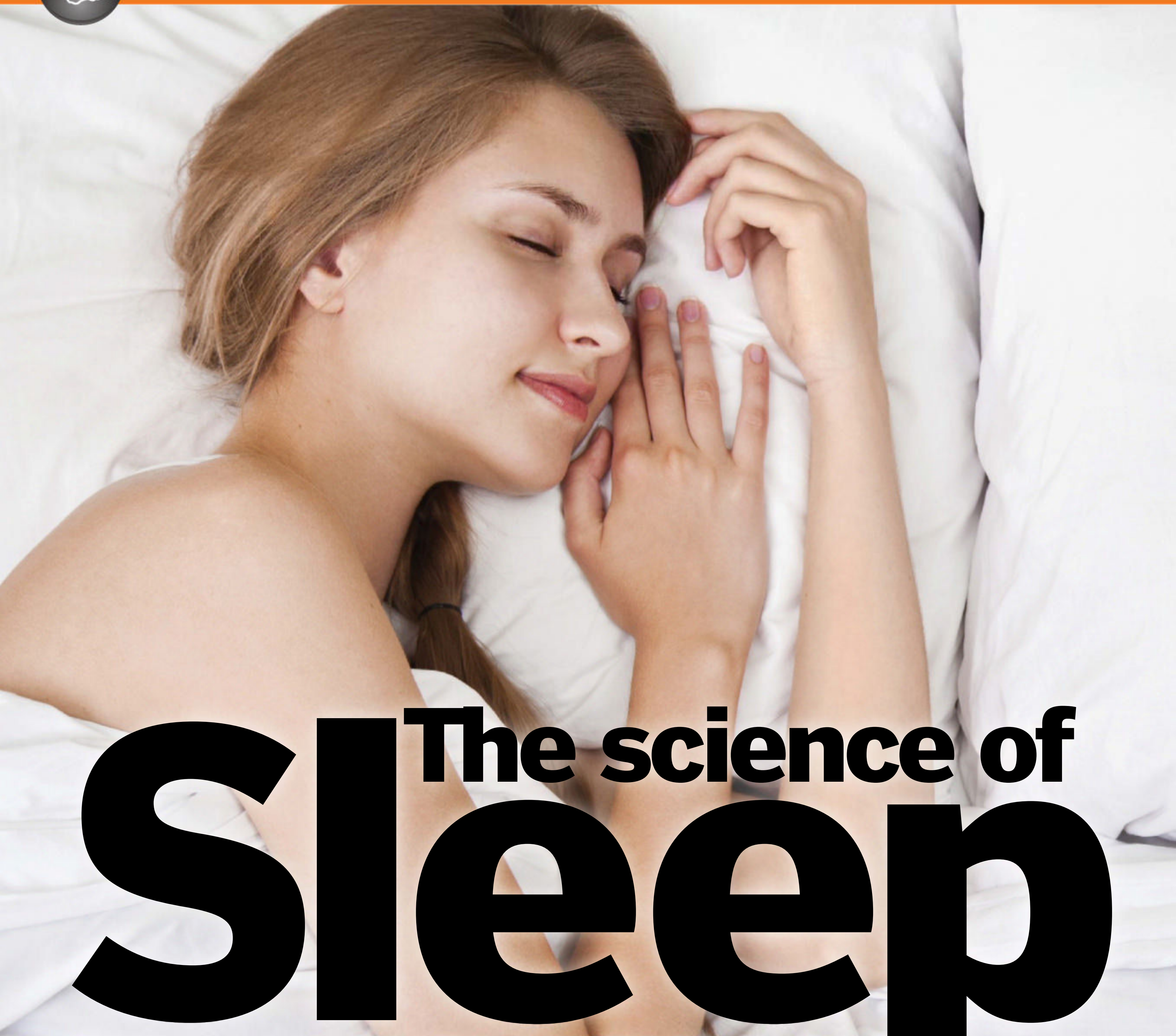


"The cell damage from viruses causes diseases"



The science of Sleep

Unravelling the mysteries behind insomnia, sleepwalking, dreams and more

We spend around a third of our lives sleeping. It is vital to our survival, but despite years of research, scientists still aren't entirely sure why we do it. The urge to sleep is all-consuming, and if we are deprived of it, we will eventually slip into slumber even if the situation is life-threatening.

Sleep is common to mammals, birds and reptiles and has been conserved through evolution, despite preventing us from performing tasks such as eating, reproducing and raising young. It is as important as food and, without it, rats will die within two or three weeks – the same period it takes to die of starvation.

There have been many ideas and theories proposed about why humans sleep, from a way to rest after the day's activities or a method for saving energy, to simply a way to fill time until we can be doing something useful. But all of these ideas are somewhat flawed. The body repairs itself just as well when we are sitting quietly, we only save around 100 calories a night by sleeping, and we wouldn't need to catch up on sleep during the day if it were just to fill empty time at night.

One of the major problems with sleep deprivation is a resulting decline in cognitive ability – our brains just don't work properly without sleep. We will find ourselves struggling with memory, learning,

Theories of why we sleep

Theory 1

Energy conservation

We save around 100 calories per night by sleeping; metabolic rate drops, the digestive system is less active, heart and breathing rates slow, and body temperature drops. However, the calorie-saving equates to just one cup of milk, which from an evolutionary perspective does not seem worth the accompanying vulnerability.

Theory 3

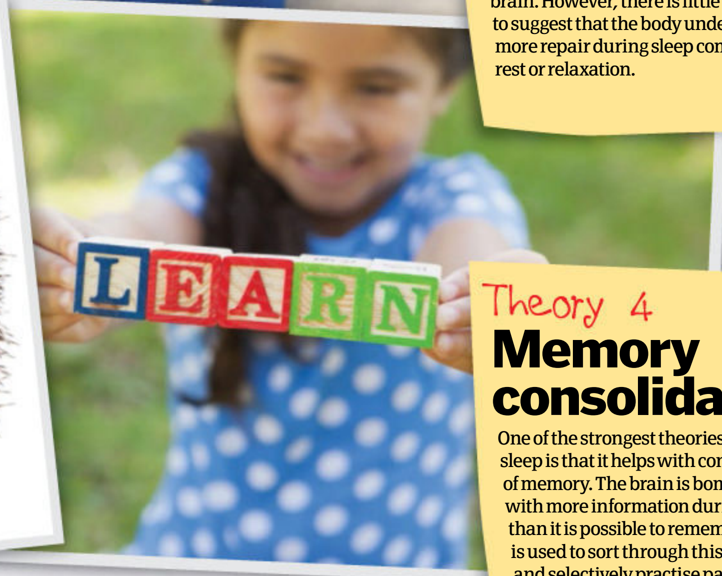
Restoration

One of the major problems with sleep deprivation is a decline in cognitive function, accompanied by a drop in mood, and there is mounting evidence that sleep is involved in restoring the brain. However, there is little evidence to suggest that the body undergoes more repair during sleep compared to rest or relaxation.

Theory 2

Evolutionary protection

An early idea about the purpose of sleep is that it is a protective adaptation to fill time. For example, prey animals with night vision might sleep during the day to avoid being spotted by predators. However, this theory cannot explain why sleep-deprived people fall asleep in the middle of the day.



Theory 4

Memory consolidation

One of the strongest theories regarding sleep is that it helps with consolidation of memory. The brain is bombarded with more information during the day than it is possible to remember, so sleep is used to sort through this information and selectively practise parts that need to be stored.

planning and reasoning. A lack of sleep can have severe effects on our mood and performance of everyday tasks, ranging from irritability, through to long term problems such as an increased risk of heart disease and even a higher incidence of road traffic accidents.

Sleep can be divided into two broad stages: non-rapid eye movement (NREM), and rapid eye movement (REM) sleep. The vast majority of our sleep (around 75 to 80 per cent) is NREM, characterised by electrical patterns in the brain known as 'sleep spindles' and high, slow delta waves. This is the time when we sleep the deepest. Without NREM sleep, our ability to form declarative memories, such as learning to associate pairs of words, can be seriously impaired. Deep sleep is important for transferring short-term memories into long-term storage. Deep sleep is also the time of peak growth hormone release in the body, which is important for cell reproduction and repair.

The purpose of REM sleep is unclear, with the effects of REM sleep deprivation proving less severe than NREM deprivation; for the first two weeks humans report little in the way of ill effects. REM sleep is the period during the night when we have our most vivid dreams, but people dream during both NREM and REM sleep. One curiosity is that during NREM sleep, dreams tend to be more concept-based, whereas REM sleep dreams are more vivid and emotional.

Some scientists argue that REM sleep allows our brains a safe place to practice dealing with situations or emotions that we might not encounter during our daily lives. During REM sleep our muscles are temporarily paralysed, preventing us acting out these emotions. Others think that it might be a way to unlearn memories, or to process unwanted feelings or emotions. Each of these ideas has its flaws, and no one knows the real answer.

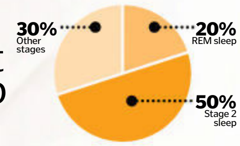
Over the next few pages we will delve into the science of sleep and attempt to make sense of the mysteries of the sleeping brain.

The sleep cycle

During the night, you cycle through five separate stages of sleep every 90 to 110 minutes

The five stages of sleep can be distinguished by changes in the electrical activity in your brain, measured by electroencephalogram (EEG). The first stage begins with drowsiness as you drift in and out of consciousness, and is followed by light sleep and then by two stages of deep sleep. Your brain activity starts to slow down, your breathing, heart rate and temperature drop, and you become progressively more difficult to wake up. Finally, your brain perks up again, resuming activity that looks much more like wakefulness, and you enter rapid eye movement (REM) sleep – the time when your most vivid dreams occur. This cycle happens several times throughout the night, and each time, the period of REM sleep grows longer.

How much time is spent in each sleep stage?



Growth hormone release
After you fall asleep, the pituitary gland ramps up its production of growth hormone.

Low temperature
Body temperature falls just before you fall asleep, and is maintained at a lower level throughout the night.

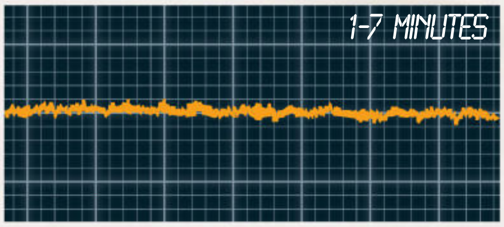
Limited movement
Muscle tone drops during sleep, but you still change position, tossing and turning.

Different when dreaming
During REM sleep, your heart rate rises, but your larger muscles are paralysed. This mean just your fingers, toes and eyes twitch as you dream.

Slow breathing
As you fall into deeper and deeper sleep, your breathing becomes slower and more rhythmic and your heart rate drops.

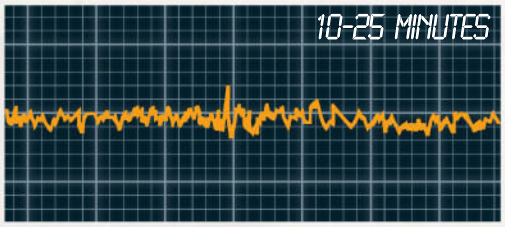
Stages of sleep

Not all sleep is the same. There are five separate stages, divided by brain activity



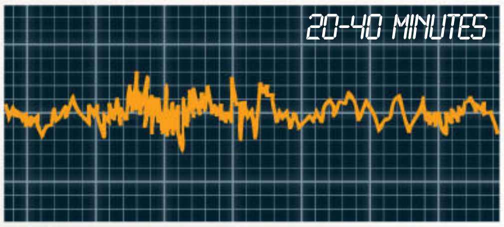
1 Drowsiness

During the first stage of sleep you are just drifting off; your eyelids are heavy and your head starts to drop. During this drowsy period, you are easily woken and your brain is still quite active. The electrical activity on an electroencephalogram (EEG) monitor starts to slow down, and the cortical waves become taller and spikier. As the sleep cycle repeats during the night, you re-enter this drowsy half-awake, half-asleep stage.



2 Light sleep

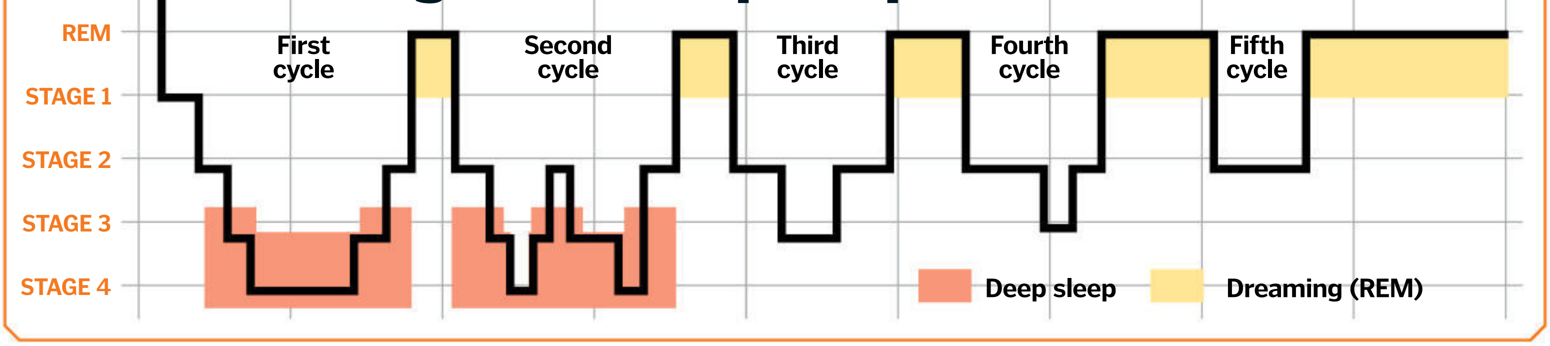
After a few minutes, your brain activity slows further, and you descend into light sleep. On the EEG monitor, this stage is characterised by further slowing in the waves, with an increase in their size and short one- or two-second bursts of activity known as 'sleep spindles'. By the time you are in the second phase of sleep, your eyes stop moving, but you can still be woken quite easily.



3 Moderate sleep

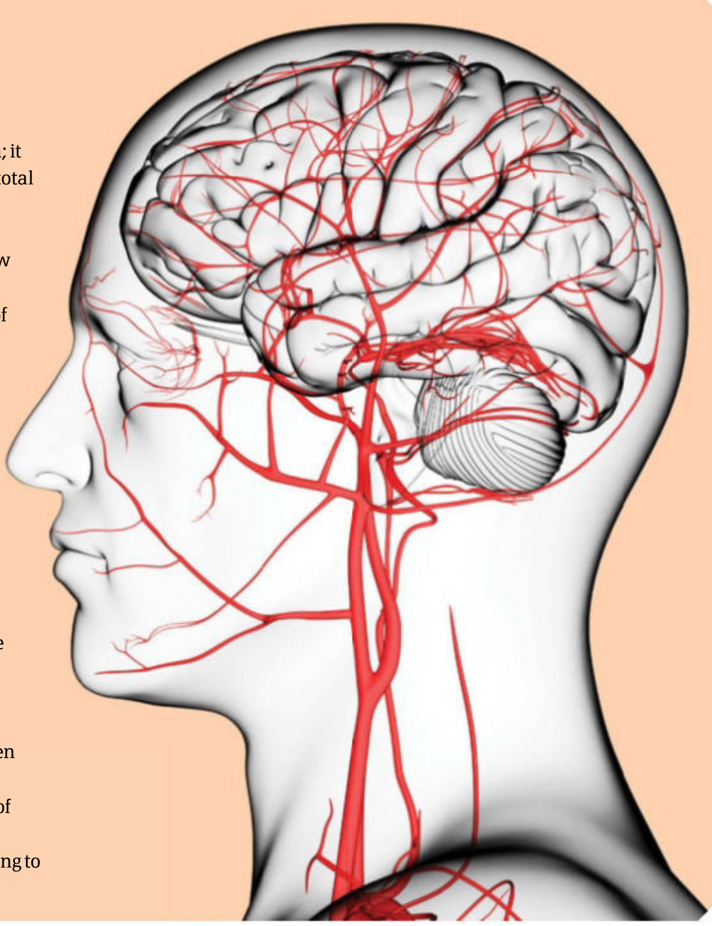
As you start to enter this third stage, your sleep spindles stop, showing that your brain has entered moderate sleep. This is then followed by deep sleep. The trace on the EEG slows still further as your brain produces delta waves with occasional spikes of smaller, faster waves in between. As you progress through stage-three sleep, you become much more difficult to wake up.

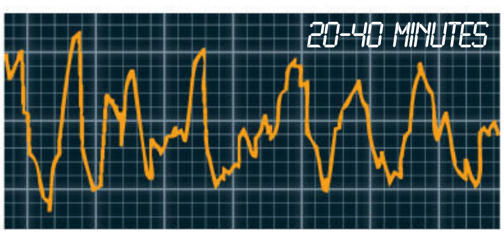
Dreaming versus deep sleep



Clearing the mind

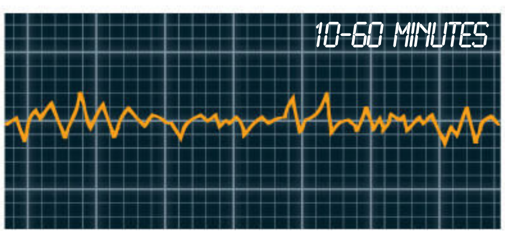
The brain is a power-hungry organ; it makes up only two per cent of the total mass of the body, but it uses an enormous 25 per cent of the total energy supply. The question is, how does it get rid of waste? The Nedergaard Lab at the University of Rochester in New York thinks sleep might be a time to clean the brain. The rest of the body relies on the lymphatic drainage system to help remove waste products, but the brain is a protected area, and these vessels do not extend upward into the head. Instead, your central nervous system is bathed in a clear liquid called cerebrospinal fluid (CSF), into which waste can be dissolved for removal. During the day, it remains on the outside, but the lab's research has shown that, during sleep, gaps open up between brain cells and the fluid rushes in, following paths along the outside of blood vessels, sweeping through every corner of the brain and helping to clear out toxic molecules.





4 Deep sleep

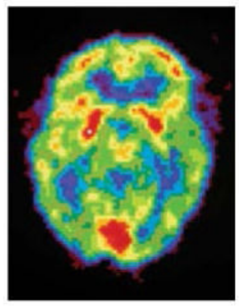
There is some debate as to whether sleep stages three and four are really separate, or whether they are part of the same phase of sleep. Stage four is the deepest stage of all, and during this time you are extremely hard to wake. The EEG shows tall, slow waves known as delta waves; your muscles will relax and your breathing becomes slow and rhythmic, which can lead to snoring.



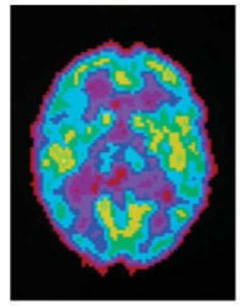
5 REM sleep

After deep sleep, your brain starts to perk up and its electrical activity starts to resemble the waking brain. This is the period of the night when most dreams happen. Your muscles are temporarily paralysed, and your eyes dart around, giving it the name rapid eye movement (REM) sleep. You cycle through the stages of sleep about every 90 minutes, experiencing between three and five dream periods each night.

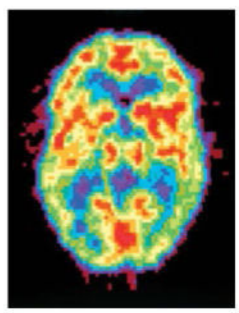
Brain activity



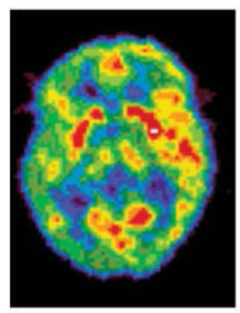
Wide awake
The red areas in this scan show areas of activity in the waking human brain, while the blue areas represent areas of inactivity.



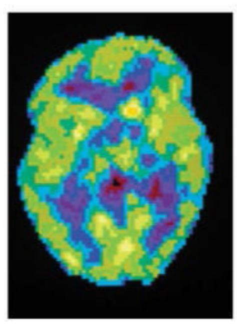
Deep sleep
During the later stages of NREM sleep, the brain is less active, shown here by the cool blue and purple colours that dominate the scan.



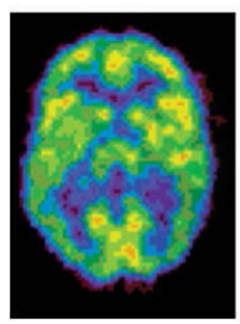
REM (dream) sleep
When dreaming, the human brain shows a lot of activity, displaying similar red patterns of activity to the waking brain.



Light sleep
In the first stages of NREM sleep, the brain is less active than when awake, but you remain alert and easy to wake up.



Sleep deprivation
The sleep-deprived brain looks similar to the brain during NREM sleep, showing patterns of inactivity.



NREM sleep
As you descend through the four stages of NREM sleep, your brain becomes progressively less active.

Sleep disorders

There are over 100 different disorders that can get in the way of a good night's sleep

Sleep is necessary for our health, so disruptions to the quality or quantity of our sleep can have a serious negative impact on daily life, affecting both physical health and mental wellbeing.

Sleep disorders fall into four main categories: difficulty falling asleep, difficulty staying awake, trouble sticking to a regular sleep pattern and abnormal sleep behaviours. Struggling with falling asleep or staying asleep is known as insomnia, and is one of the most familiar sleep disorders; around a third of the population will experience it during their lifetime. Difficulty staying awake, or hypersomnia, is less common. The best-known example is narcolepsy, which is when sufferers experience excessive daytime sleepiness, accompanied by uncontrollable short periods of sleep during the day. Trouble sticking to a regular sleeping pattern can either be caused by external disruption to normal day-to-day rhythms, for example by jet lag or shift work. It can also be the result of an internal problem with the part of the brain responsible for setting the body clock.

Abnormal sleep behaviours include problems like night terrors, sleepwalking and REM-sleep behaviour disorder. Night terrors and sleepwalking most commonly affect children, and tend to resolve themselves with age, but other sleep behaviours persist into adulthood. In REM-sleep behaviour disorder, the normal muscle paralysis that accompanies dreaming fails, and people begin to act out their dreams.

Treatment for different sleep disorders varies depending on the particular problem, and can be as simple as making the bedroom environment more conducive to restful sleep.

"Treatment for different sleep disorders varies"

A continuous positive airway pressure (CPAP) machine pumps air into a close-fitting mask, preventing the airway from collapsing

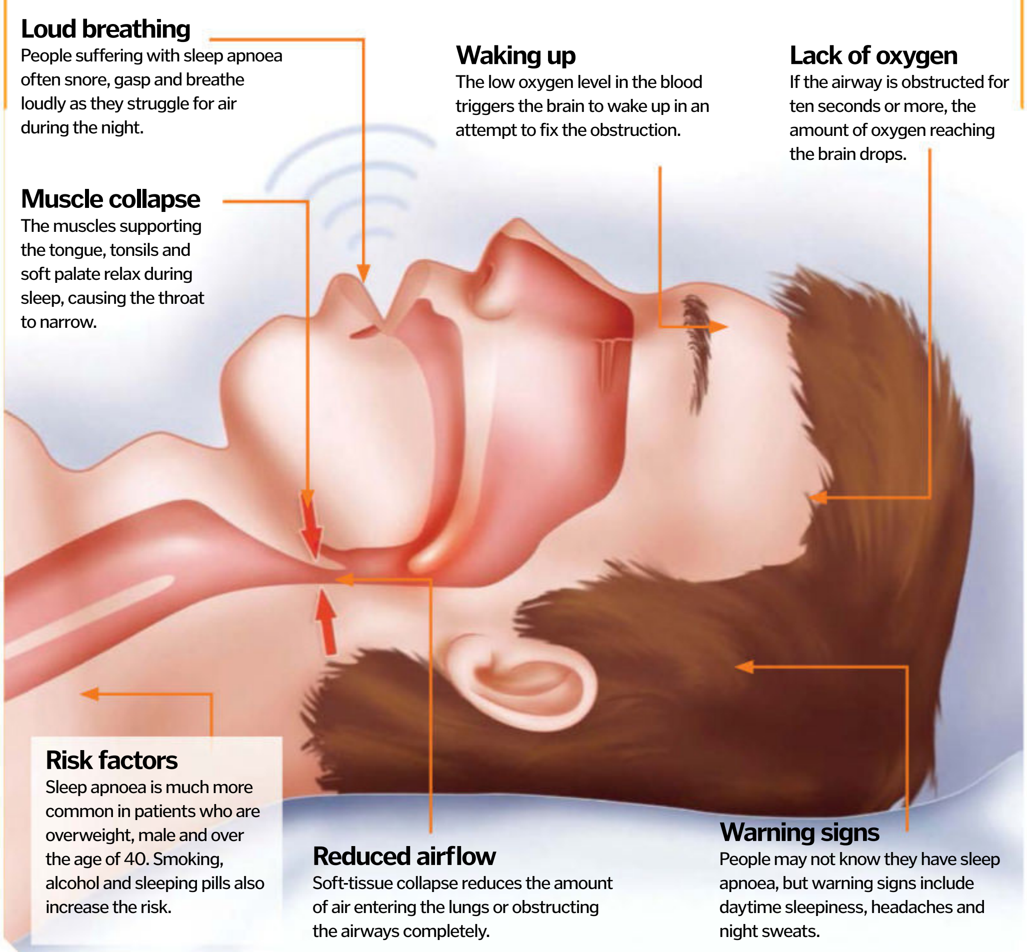
Sleepwalking

Sleepwalking affects between one and 15 per cent of the population, and is much more common in children than in adults, tending to happen less and less after the age of 11 or 12. Sleepwalkers might just sit up in their bed, but can sometimes perform complex behaviours, such as walking, getting dressed, cooking, or even driving a car. Although sleepwalkers seem to be acting out their dreams, sleepwalking tends to occur during the deep-sleep phase of NREM sleep and not during REM sleep.

Sleepwalkers can perform complicated actions while in deep NREM sleep

Sleep apnoea

Sleep apnoea is a dangerous sleep disorder. It is when the walls of the airways relax so much during the night that breathing is interrupted for ten seconds or more, restricting the supply of oxygen to the brain. The lack of oxygen initiates a protective response, pulling the sufferer out of deep sleep to protect them from damage. This can cause people to wake up, but often it will just put them into a different sleep stage, interrupting their rest and causing feelings of tiredness the next day.



Narcolepsy

Narcolepsy is a chronic condition that causes people to suddenly fall asleep during the daytime. In the United States, it affects one in every 3,000 people. Narcoleptics report excessive daytime sleepiness, accompanied by a lack of energy and impaired ability to concentrate. They fall asleep involuntarily for periods lasting just a few seconds at a time, and some can continue to perform tasks such as writing, walking, or even driving during these microsleeps. In 70 per cent of cases, narcolepsy is accompanied by cataplexy, where the muscles go limp and become difficult to control. It has been linked to low levels of the neurotransmitter hypocretin, which is responsible for promoting wakefulness in the brain.

People with narcolepsy fall asleep involuntarily during the day

Insomnia

Insomniacs have difficulty falling asleep or staying asleep. Sufferers can wake up during the night, wake up unusually early in the morning, and report feeling tired and drained during the day. Stress is thought to be one of the major causes of this sleep disruption, but it is also associated with mental health problems like depression, anxiety and psychosis, and with underlying medical conditions ranging from lung problems to hormone imbalances. After underlying causes have been ruled out, management of insomnia generally involves improving 'sleep hygiene' by sticking to regular sleep patterns, avoiding caffeine in the evening and keeping the bedroom free from light and noise at night.

One in three people in the UK will experience insomnia in their lifetime

Sleep studies

The most common type of sleep study is a polysomnogram (PSG), which is an overnight test performed in a specialist sleep facility. Electrodes are placed on the chin, scalp and eyelids to monitor brain activity and eye movement, while pads are placed on the chest to track heart rate and breathing. Blood pressure is also monitored throughout the night, and the amount of oxygen in the bloodstream can be tracked using a device worn on the finger. The equipment monitors how long it takes a patient to fall asleep, and then to follow their brains and bodies as they move through each of the five sleep stages.

Electrodes monitor brain activity, eye movement, heart rate and breathing in sleep studies

How to get a good night's sleep

Understanding your biological clock is the key to a healthy night's sleep

Your body is driven by an internal circadian master clock known as the suprachiasmatic nucleus, which is set on a time scale of roughly 24 hours. This biological clock is set by sunlight; blue light hits special receptors in your eyes, which feed back to the master clock and on to the pineal gland. This suppresses the production of the sleep hormone melatonin and tells your brain that it is time to wake up.

Disruptions in light exposure can play havoc with your sleep, so it is important to ensure that your bedroom is as dark as possible. Many electronic devices produce enough light to reset your biological clock, and using backlit screens late at night can confuse your brain, preventing the production of melatonin and delaying your sleep.

Ensuring you see sunlight in the morning can help to keep your circadian clock in line, and sticking to a regular sleep schedule, even at the weekends, helps to keep this rhythm regular.

Another important factor in a good night's sleep is winding down before bed. Stimulants like caffeine and nicotine keep your brain alert and can seriously disrupt your sleep. Even depressants like alcohol can have a negative effect; even though it calms the brain, it interferes with normal sleep cycles, preventing proper deep and REM sleep.

The blue light from televisions, mobile phones and computer screens disrupts your circadian rhythm

The dangers of sleep deprivation

Lack of sleep doesn't just make you tired – it can have dangerous unseen effects

1 IMPAIRED JUDGEMENT

Sleep deprivation impacts your visual working memory, making it hard to distinguish between relevant and irrelevant stimuli, affecting emotional intelligence, behaviour and stress management.

2 WEIGHT GAIN

Sleep deprivation affects the levels of hormones involved in regulating appetite. Levels of leptin (the hormone that tells you how much stored fat you have) drop, and levels of the hunger hormone ghrelin rise.

3 RAISED BLOOD PRESSURE

Poor sleep can raise blood pressure, and in the long term is associated with an increased risk of diseases such as coronary heart disease and stroke. This danger is increased in people with sleep apnoea.

4 INCREASED ACCIDENTS

In the USA it is estimated that 100,000 road accidents each year are the result of driver fatigue, and over a third of drivers have admitted to falling asleep behind the wheel.

5 MOOD DISORDERS

Mental health problems are linked to sleep disorders, and sleep deprivation can play havoc with neurotransmitters in the brain, mimicking the symptoms of depression, anxiety and mania.

6 HALLUCINATIONS

Severe sleep deprivation can lead to hallucinations – seeing things that aren't really there. In rare cases , it can lead to temporary psychosis or symptoms that resemble paranoid schizophrenia.

Sleep myths debunked

The science behind five of the most common myths relating to sleep

"Counting sheep helps you sleep"

This myth was put to the test by the University of Oxford, who challenged insomniacs to either count sheep, imagine a relaxing scene, or do nothing as they tried to fall asleep. When they imagined a relaxing scene, the participants fell asleep an average of 20 minutes earlier than when they tried either of the other two methods.

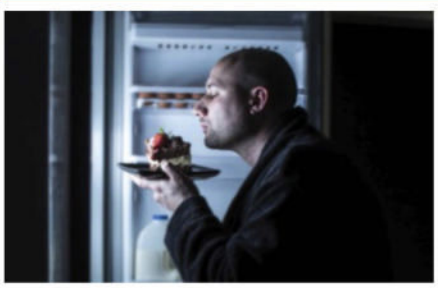
"Yawning wakes you up"

Yawning has long been associated with tiredness and was fabled to provide more oxygen to a sleepy brain, but this is not the case. New research suggests that we actually yawn to cool our brains down, using a deep intake of breath to keep the brain running at its optimal temperature.

"Teenagers are lazy"

Sleep habits start to change just before puberty, and between the ages of ten and 25, people need around nine hours of sleep every night. Teens can also experience a shift in their circadian rhythm, called sleep phase delay, pushing back their natural bedtime by around two hours, and encouraging them to sleep in.

"You should never wake a sleepwalker"



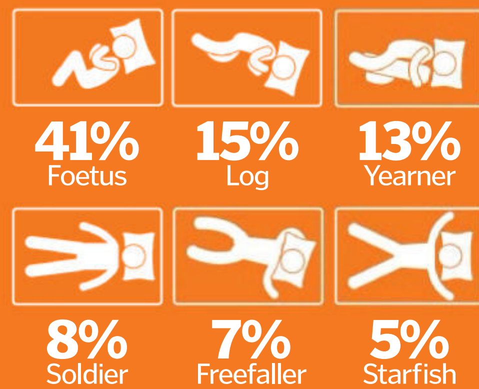
Many people have heard that waking a sleepwalker might kill them, but there is little truth behind these tales. Waking a sleepwalker can leave them confused and disorientated, but the act of sleepwalking in itself can be much more dangerous. Gently guiding a sleepwalker back to their bed is the safest option, but waking them carefully shouldn't do any harm.

"Cheese gives you nightmares"

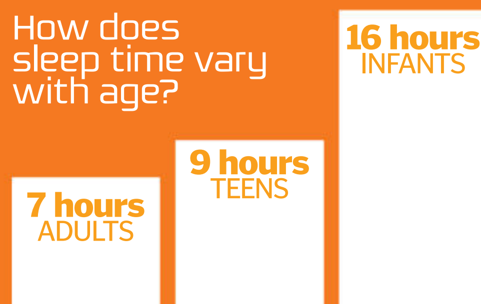
The British Cheese Board conducted a study in an attempt to debunk this myth by feeding 20g (0.7oz) of cheese to 200 volunteers every night for a week and asking them to record their dreams. There were no nightmares, but strangely 75 per cent of men and 85 per cent of the women who ate Stilton reported vivid dreams.

SLEEP STATS

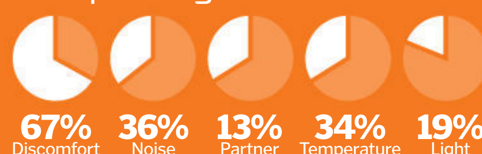
What are the most common sleeping positions?



How does sleep time vary with age?

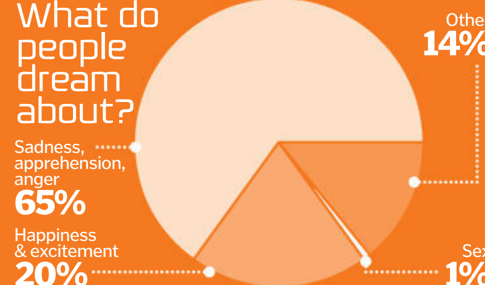


What keeps the UK up at night?

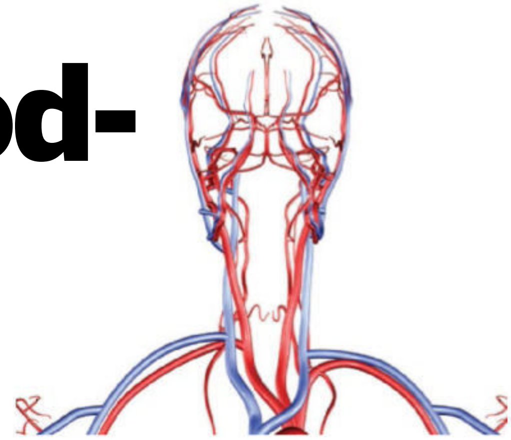


Which country sleeps the longest?

What do people dream about?



What is the blood-brain barrier?



How does this gateway control the molecules that pass from the blood into the brain

The blood-brain barrier (BBB) is an essential group of cells that line the blood vessels in the central nervous system (brain and spinal cord). They allow passage of materials between the clear fluid surrounding the brain (cerebrospinal fluid) and the red blood cells in arteries, veins and capillaries. The key advantage of having such a barrier is that it prevents large micro-organisms passing into the brain and causing infections. While infections in other areas are common (such as after a cut finger, or mild chest infections), those affecting the brain are much rarer. However when they do occur (eg meningitis), they are potentially life threatening as they are very difficult to treat.

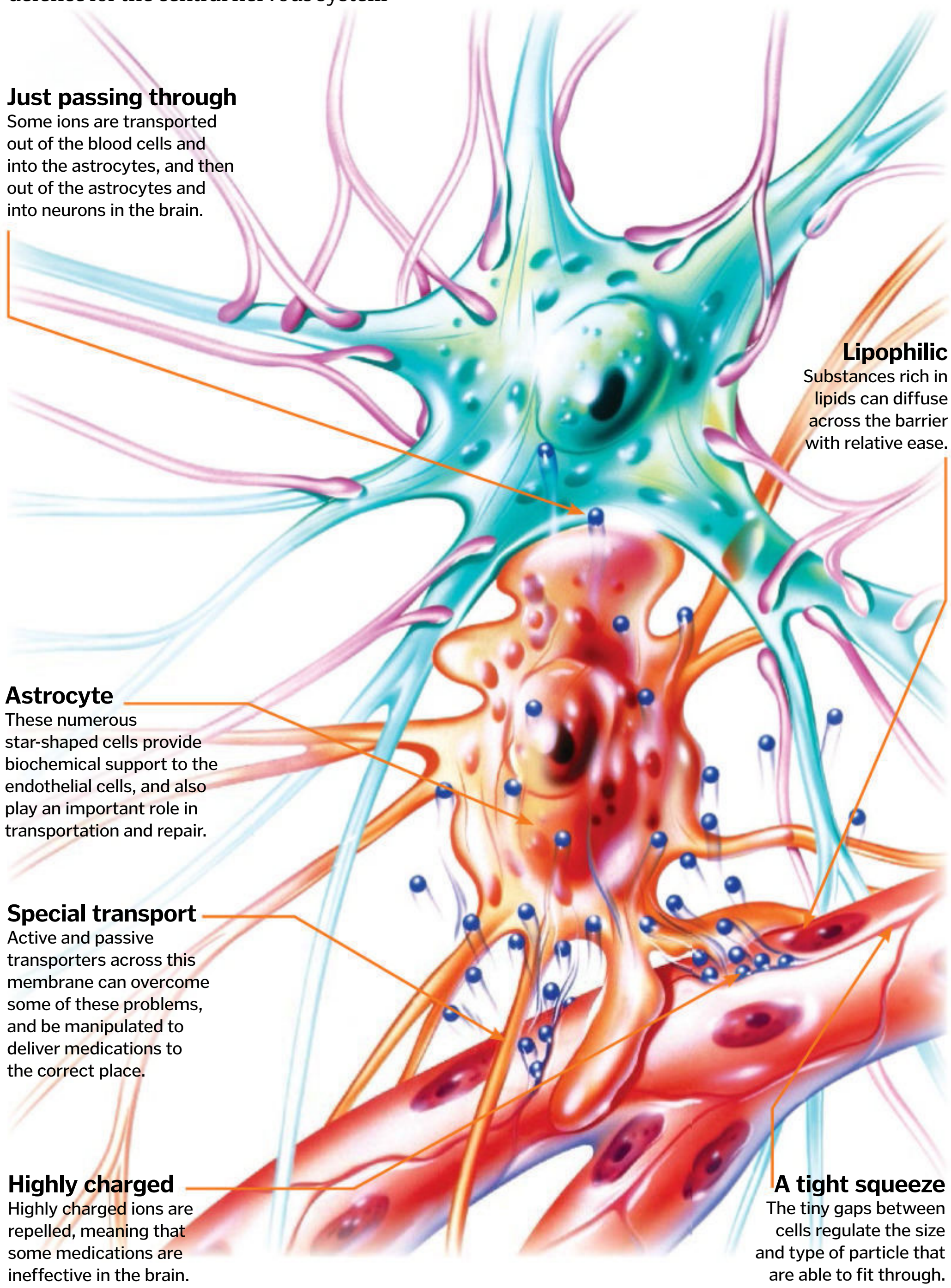
The tight junctions between cells regulate the size and type of particle that pass between them, including oxygen molecules, carbon dioxide molecules, nutrients and hormones. Since it's so effective, it also stops medications from entering the brain (such as certain antibiotics), so while they are effective in the rest of the body, they are ineffective in this vital organ. Overcoming this is a major aim of doctors in the next decade, and the battle has already started. Manipulating the blood-brain barrier's natural transport mechanisms and delivering drugs within nanoparticles to squeeze through the tight junctions are just two examples of the modern techniques that are under development.

Crossing the BBB

The endothelial lining of the blood-brain barrier loves lipids (fatty molecules), but it hates particles with high electrical charges (ions) and large substances. Thus the ideal substance is small, rich in lipids and has a low electrical charge. Barbiturates are such an example, as they freely flow across the blood-brain barrier to suppress brain function; they act as sedatives and antidepressants. However this free movement comes with risks – too much of it will accumulate and slow the brain to a point where you can lose consciousness and even stop breathing.

Breaking down the barrier

This built-in gateway is the main line of defence for the central nervous system



Pituitary gland up close

What does this hormone factory do and why couldn't we live without it?

The pea-sized pituitary gland is found at the base of the brain, close to the hypothalamus. It looks a relatively insignificant part of the brain, but it plays a role in many vital systems.

Often referred to as the 'master gland', it not only releases hormones that control various functions, but it also prompts the activity of other glands like the ovaries and testes.

The pituitary gland comprises three sections called lobes: the anterior, the posterior and the intermediate – the latter of which is considered part of the anterior lobe in humans. These work together with the hypothalamus, which monitors hormones in the blood and stimulates the pituitary gland to produce/release the appropriate hormone(s) if levels fall too low.

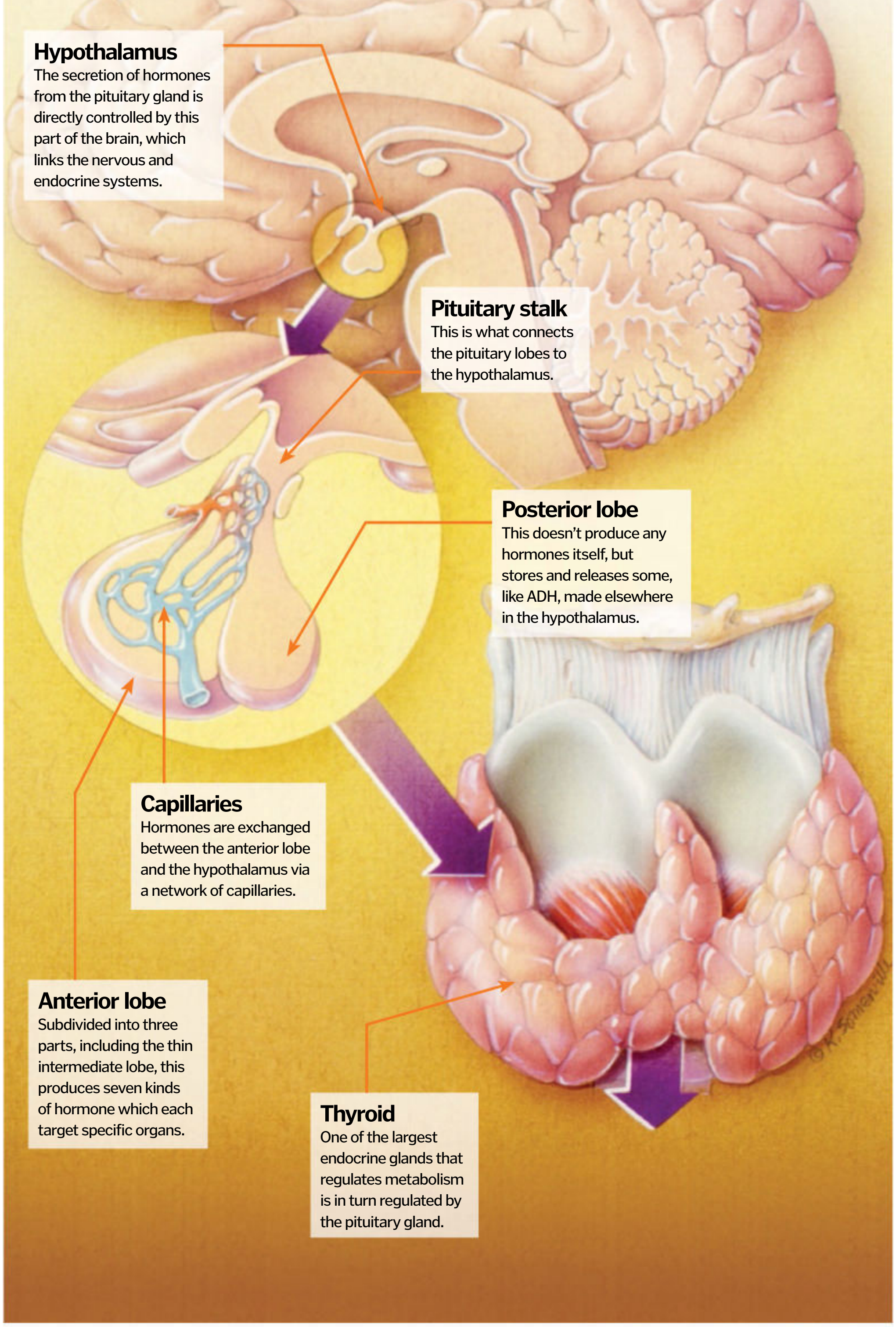
The anterior lobe produces seven important hormones, which include those that regulate growth and reproduction. Adrenocorticotropic hormone (ACTH) targets the adrenal glands to produce cortisol and controls metabolism, while luteinising hormone triggers ovulation in women and stimulates testosterone production in men. The posterior lobe, meanwhile, doesn't *generate* any hormones itself, but stores two: antidiuretic hormone (ADH), which decreases urine production by making the kidneys return more water to the blood, and oxytocin, which tells the uterus to contract during childbirth and also prompts milk production.

Gigantism in focus

The pituitary gland also produces growth hormone, which in adults controls the amount of muscle and fat in the body and plays a key role in the immune system. In children, of course, growth hormone has a very noticeable effect in increasing height and bulk until adulthood. However, sometimes the pituitary gland becomes hyperactive – often as a result of a benign tumour – and produces excess growth hormone. In these cases, a person can grow to a far-beyond-average height, with hands, feet and facial features growing proportionally. While this might not seem so bad, gigantism is nearly always accompanied by other health issues, such as skeletal problems, severe headaches and more life-threatening conditions like heart disorders. If diagnosed early, treatment such as drugs that inhibit growth hormone production and surgical removal of the tumour can help avert the more serious conditions of gigantism.

The master gland in context

Where does this vitally important hormone manufacturer sit within the human brain?



Human digestion

How does food get turned into energy?

The digestive system is a group of organs that process food into energy that the human body can use to operate. It is an immensely complex system that stretches all the way between the mouth and the anus.

Primary organs that make up the system are the mouth, oesophagus, stomach, small intestine, large intestine and the anus. Each organ has a different function so that the maximum amount of energy is gained from the food, and the waste can be safely expelled from the body. Secondary organs, such as the liver, pancreas and gall bladder, aid the digestive process alongside mucosa cells, which line all hollow organs and produce a secretion which helps the food pass smoothly through them. Muscle contractions called peristalsis also help to push the food throughout the system.

The whole digestive process starts when food is taken into the body through the mouth. Mastication (chewing) breaks down the food into smaller pieces and saliva starts to break starch in these pieces of food into simpler sugars as they are swallowed and move into the oesophagus. Once the food has passed through the oesophagus, it passes into the stomach. It can be stored in the stomach for up to four hours.

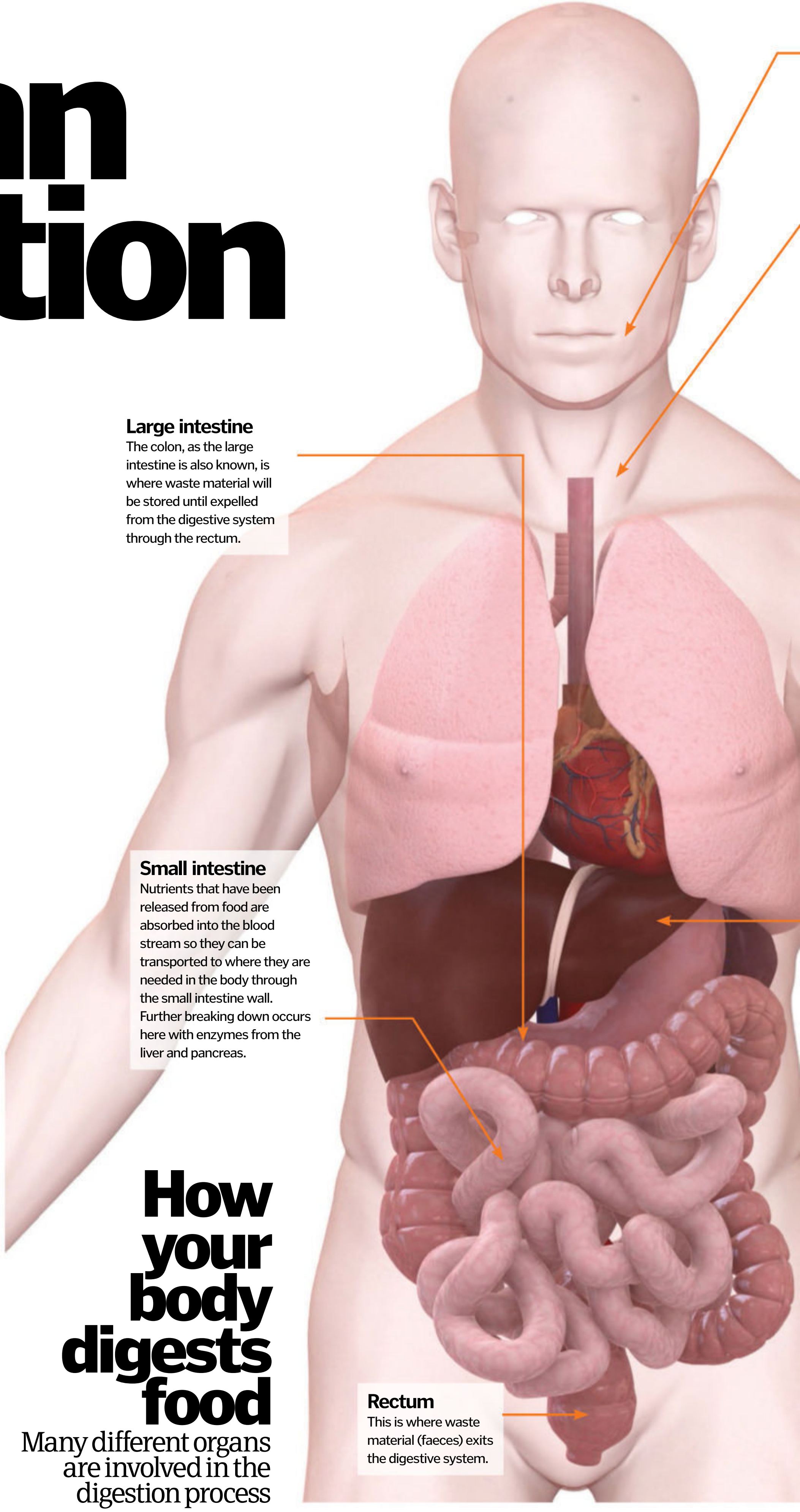
The stomach will eventually mix the food with the digestive juices that it produces, which will break down the food further into simpler molecules. These molecules then move into the small intestine slowly, where the final stage of chemical breakdown occurs through exposure to juices and enzymes released from the pancreas, liver and glands in the small intestine. All the nutrients are then absorbed through the intestinal walls and transported around the body through the blood stream.

After all nutrients have been absorbed from food through the small intestine, resulting waste material, including fibre and old mucosa cells, is then pushed into the large intestine where it will remain until expelled by a bowel movement.

"Nutrients are then absorbed through the intestinal walls and transported around the body"

How your body digests food

Many different organs are involved in the digestion process



How does our stomach work?

The stomach is one of the most crucial organs within the digestive system

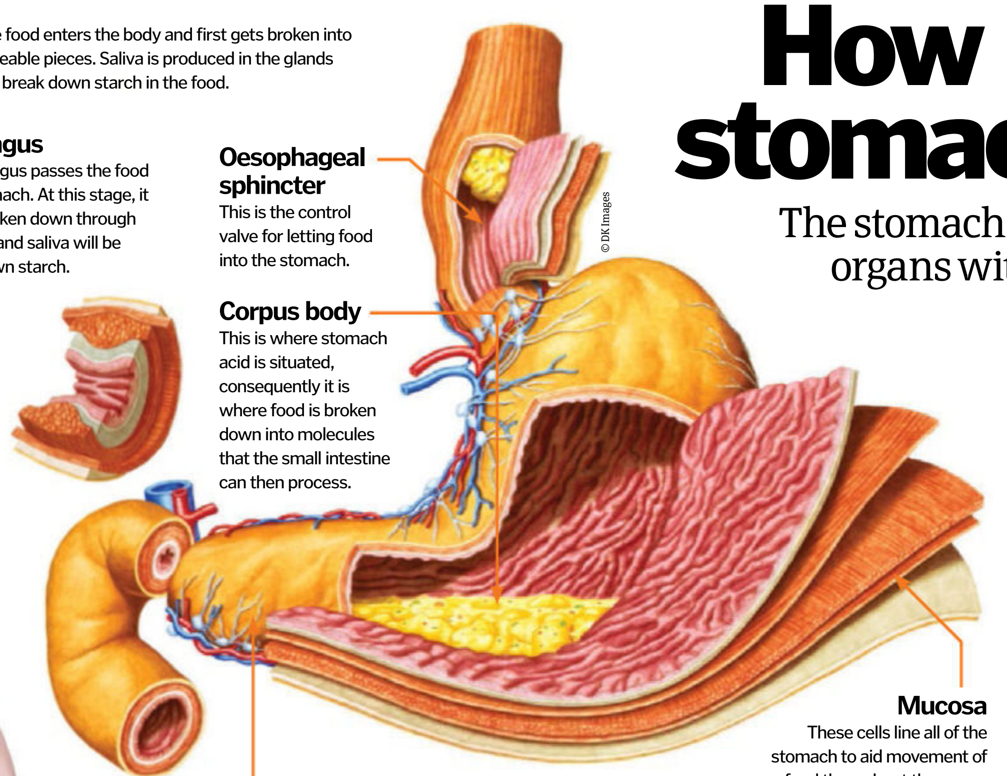
The stomach's function is to break down food into simple molecules before it moves into the small intestine where nutrients are absorbed. The organ actually splits into four distinct parts, all of which have different functions. The uppermost section is the cardia, where food is first stored, the fundus is the area above the corpus body, which makes up the main area of the stomach where food is mixed with stomach acid. The final section is the antrum, containing the pyloric sphincter, which is in control of emptying the stomach contents into the small intestine. Food is passed down into the stomach by mucosa and peristalsis through the oesophageal sphincter, and then mixed in the stomach with acids and juices by muscle contractions.

Mouth
This is where food enters the body and first gets broken into more manageable pieces. Saliva is produced in the glands and starts to break down starch in the food.

Oesophagus
The oesophagus passes the food into the stomach. At this stage, it has been broken down through mastication and saliva will be breaking down starch.

Oesophageal sphincter
This is the control valve for letting food into the stomach.

Corpus body
This is where stomach acid is situated, consequently it is where food is broken down into molecules that the small intestine can then process.



Mucosa
These cells line all of the stomach to aid movement of food throughout the organ.

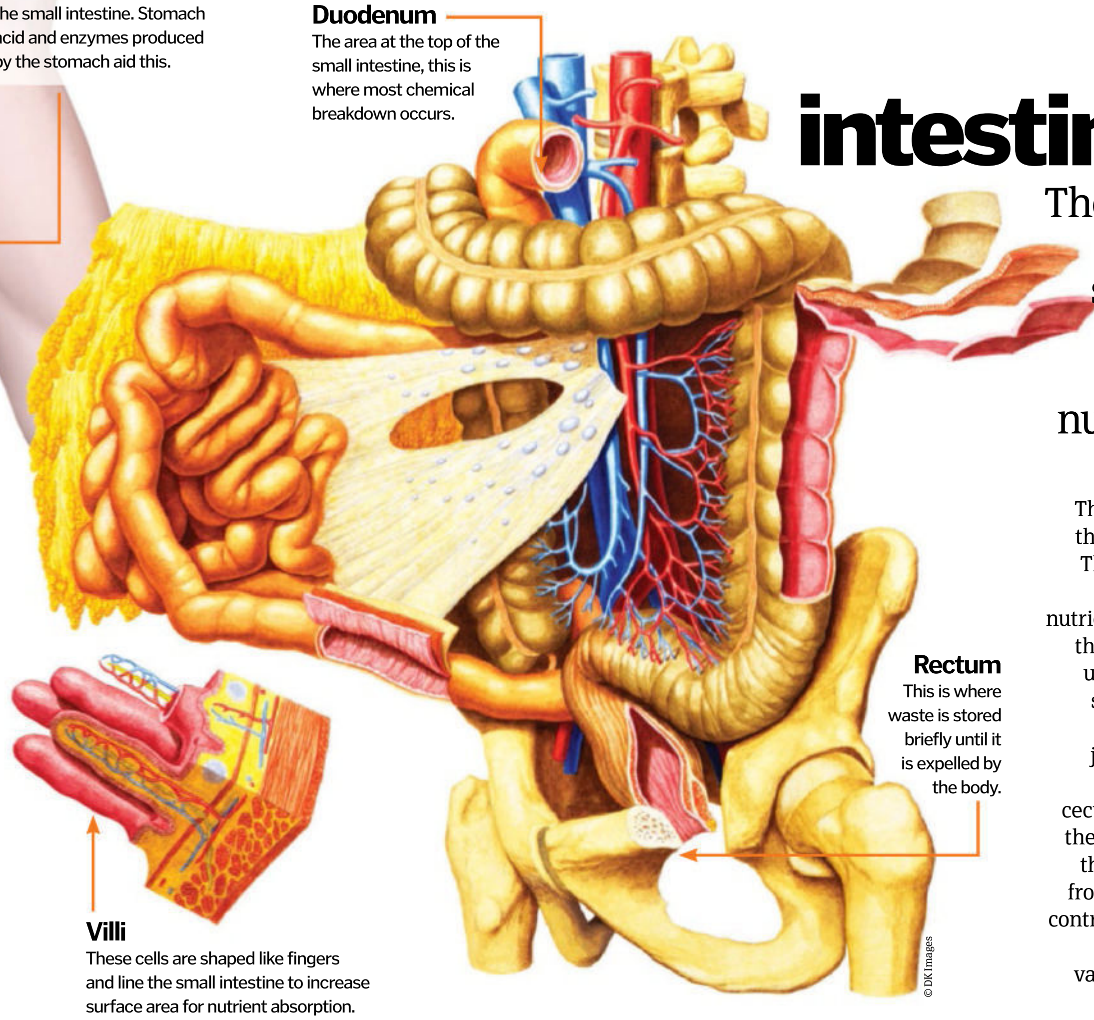
Stomach
This is where food is broken down to smaller molecules which can then be passed into the small intestine. Stomach acid and enzymes produced by the stomach aid this.

How the intestine works

The intestine is a crucial part of the digestive system that is heavily involved in breaking down and absorbing nutrients released from ingested food

The intestine splits into two distinct parts, the small intestine and the large intestine. The small intestine is where the food goes through final stages of digestion and nutrients are absorbed into the blood stream, the large intestine is where waste is stored until expelled through the anus. Both the small and large intestines can be further divided into sections, the duodenum, jejunum and ileum are the three distinct sections of the small intestine and the cecum, colon and rectum are the sections of the large intestine. As well as storing waste, the large intestine removes water and salt from the waste before it is expelled. Muscle contractions and mucosa are essential for the intestine to work properly, and we see a variation of mucosa, called villi, present in the lower intestine.

Duodenum
The area at the top of the small intestine, this is where most chemical breakdown occurs.



Rectum
This is where waste is stored briefly until it is expelled by the body.

Villi
These cells are shaped like fingers and line the small intestine to increase surface area for nutrient absorption.

What causes altitude sickness?

Discover the effects that dizzying heights can have on the human body

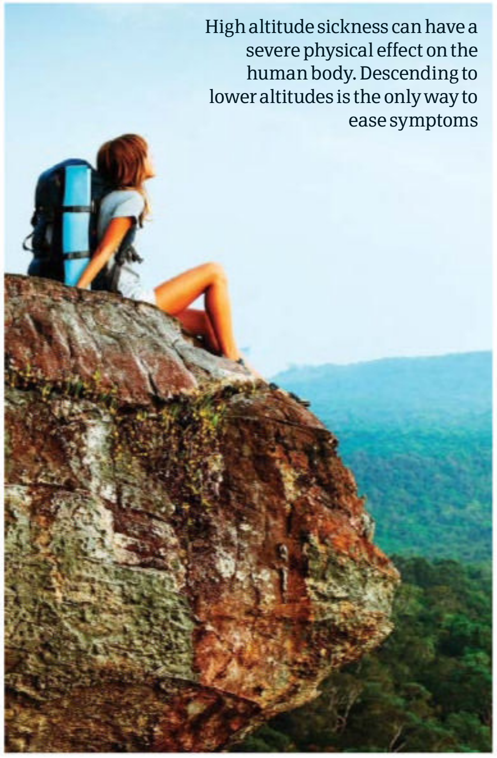
Adventurous explorers can spend months training prior to scaling mountain peaks, but regardless of fitness level, high altitudes can take its toll on the human body.

Between around 1,524 and 3,505 metres (5,000 and 11,500 feet) above sea level is considered 'high altitude'. At this level, most travellers will start to feel the effects of high altitude sickness as they attempt to acclimatise to the change in atmosphere that happens at this height.

The most common symptom is shortness of breath, which is due to a lack of atmospheric pressure. At these heights, air molecules are more dispersed, so less oxygen can be inhaled. In order to compensate, your heart rate will increase and the body will produce more red blood cells, making it easier to transport oxygen around the body.

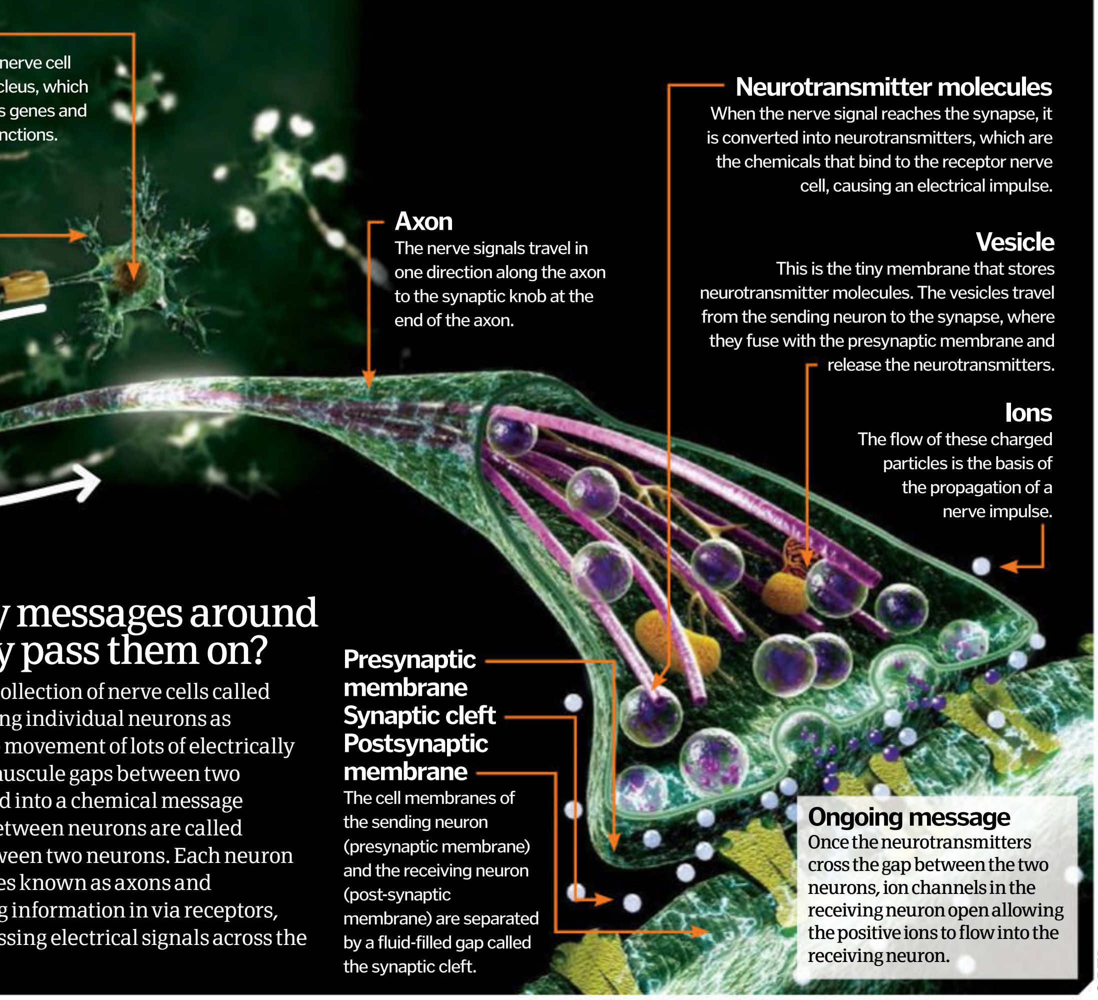
The low humidity levels at high altitude can also cause moisture in the skin and lungs to evaporate quicker, so dehydration is a real threat. Your face, legs and feet may start to swell as the body attempts to retain fluid by holding more water and sodium in the kidneys.

Difficulty sleeping is also common, and symptoms of high altitude sickness can get progressively worse the higher you climb, including mood changes, headaches, dizziness, nausea and loss of appetite.



High altitude sickness can have a severe physical effect on the human body. Descending to lower altitudes is the only way to ease symptoms

How does a synapse work?



Trillions of neurons carry messages around the body, but how do they pass them on?

The nervous system involves a complex collection of nerve cells called neurons. Nerve messages can travel along individual neurons as electrical nerve impulses caused by the movement of lots of electrically charged ion particles. In order to cross the minuscule gaps between two neurons, the nerve message must be converted into a chemical message capable of jumping the gap. These tiny gaps between neurons are called synapses, forming the main contact zone between two neurons. Each neuron consists of a cell body and branching structures known as axons and dendrites. Dendrites are responsible for taking information in via receptors, while axons transmit information away by passing electrical signals across the synapse from one neuron to another.

Adrenaline

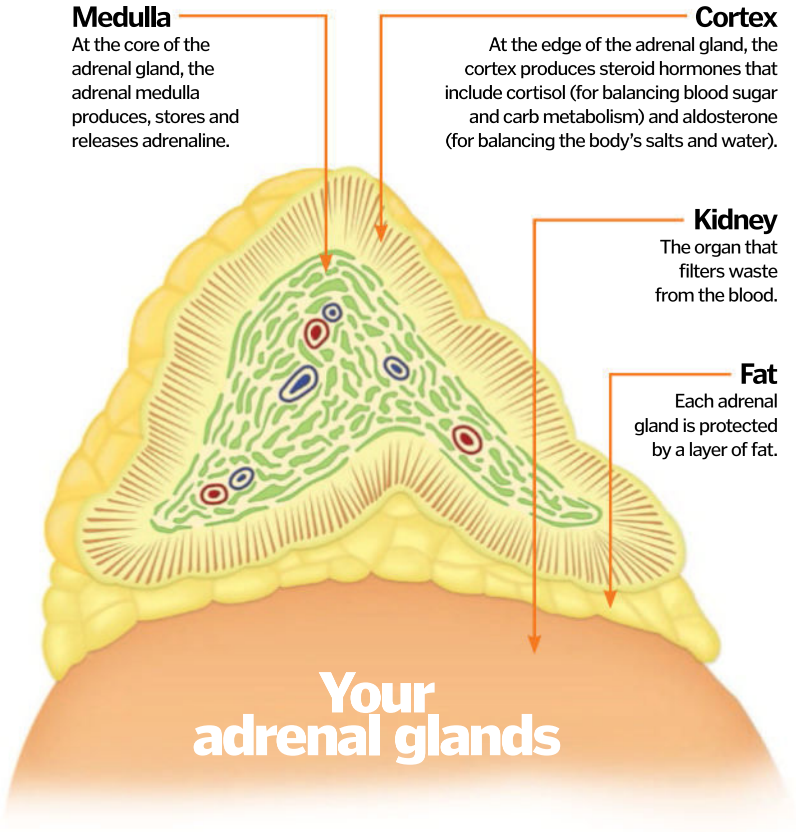
Discover the science behind your body's amazing chemical coping mechanism

Nestling on a layer of fat located just above each of your kidneys are the body's adrenal glands. Around 8cm long, the adrenal glands produce hormones that affect your body's consumption of energy as well as your stress responses.

Adrenal glands consist of two main layers of hormone-secreting cells: the outer cortex and the inner medulla. While the cortex produces energy-balancing hormones, the medulla produces a chemical called epinephrine, which we know better as adrenaline. Identified in 1900, adrenaline is a fast-acting hormone that helps the body deal with unexpected stresses – not to mention high levels of excitement – by upping your heart rate and the flow of blood to your muscles.

The effect of this is that your blood vessels and air passages dilate, meaning that more blood passes to the muscles and more oxygen gets to the lungs quicker, temporarily improving the body's physical performance and potentially saving your life.

"Adrenaline is a fast-acting hormone that helps the body deal with stresses"



Human respiration

Respiration is crucial to an organism's survival. The process of respiration is the transportation of oxygen from the air that surrounds us into the tissue cells of our body so that energy can be broken down

The primary organs used for respiration in humans are the lungs. Humans have two lungs, with the left lung being divided into two lobes and the right into three. Lungs have between 300–500 million alveoli, which is where gas exchange occurs.

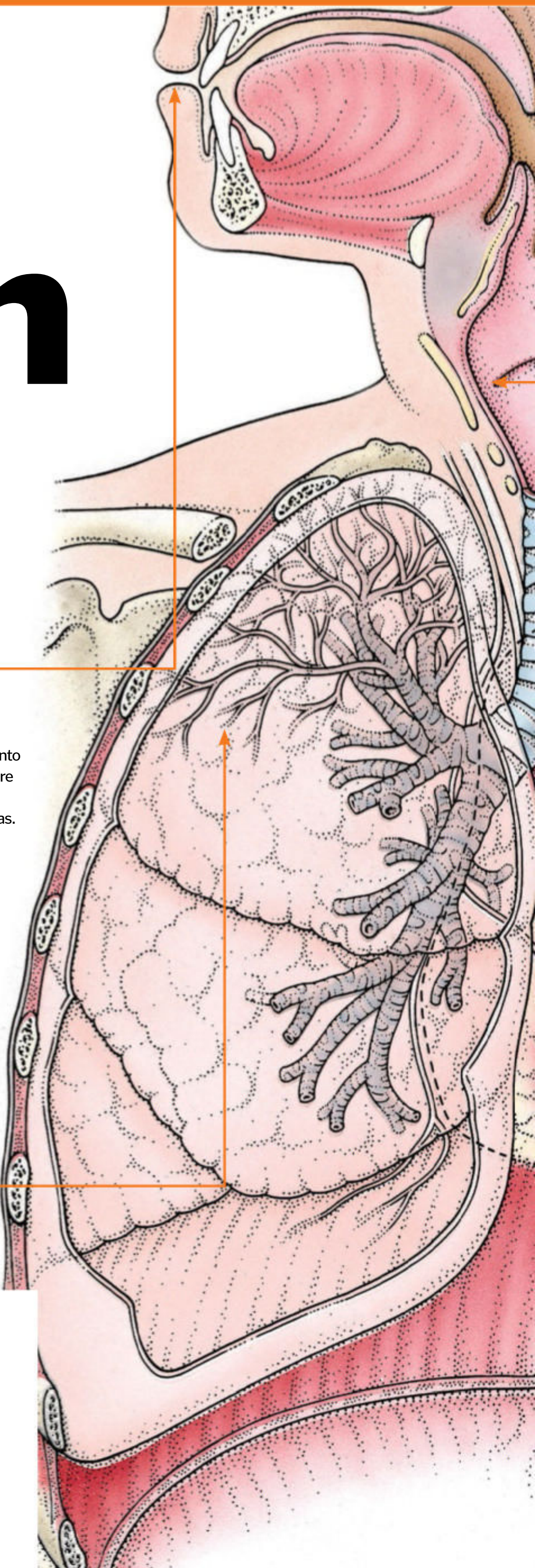
Respiration of oxygen breaks into four main stages: ventilation, pulmonary gas exchange, gas transportation and peripheral gas exchange. Each stage is crucial in getting oxygen to the body's tissue, and removing carbon dioxide. Ventilation and gas transportation need energy to occur, as the diaphragm and the heart are used to facilitate these actions, whereas gas exchanging is passive. As air is drawn into the lungs at a rate of between 10-20 breaths per minute while resting, through either your mouth or nose by diaphragm contraction, and travels through the pharynx, then the larynx, down the trachea, and into one of the two main bronchial tubes. Mucus and cilia keep the lungs clean by catching dirt particles and sweeping them up the trachea.

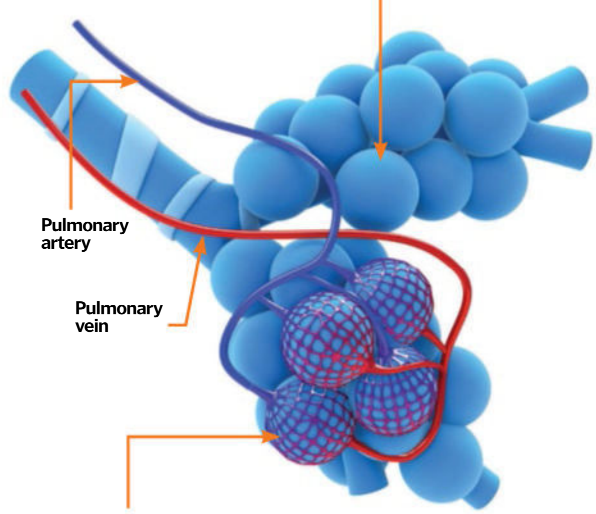
When air reaches the lungs, oxygen is diffused into the bloodstream through the alveoli and carbon dioxide is diffused from the blood into the lungs to be exhaled. Diffusion of gases occurs because of differing pressures in the lungs and blood. This is also the same when oxygen diffuses into tissue around the body. When blood has been oxygenated by the lungs, it is transferred around the body to where it is most needed in the bloodstream. If the body is exercising, the breathing rate increases and, consequently, so does the heart rate to ensure that oxygen reaches tissues that need it. Oxygen is then used to break down glucose to provide energy for the body. This happens in the mitochondria of cells. Carbon dioxide is one of the waste products of this, which is why we get a build up of this gas in our body that needs to be transported back into the lungs to be exhaled.

The body can also respire anaerobically, but this produces far less energy and instead of producing co2 as a byproduct, lactic acid is produced. The body then takes time to break this down after exertion has finished as the body has a so-called oxygen debt.

1. Nasal passage/ oral cavity
These areas are where air enters into the body so that oxygen can be transported into and around the body to where it's needed. Carbon dioxide also exits through these areas.

5. Alveoli
The alveoli are tiny little sacs which are situated at the end of tubes inside the lungs and are in direct contact with blood. Oxygen and carbon dioxide transfer to and from the blood stream through the alveoli.





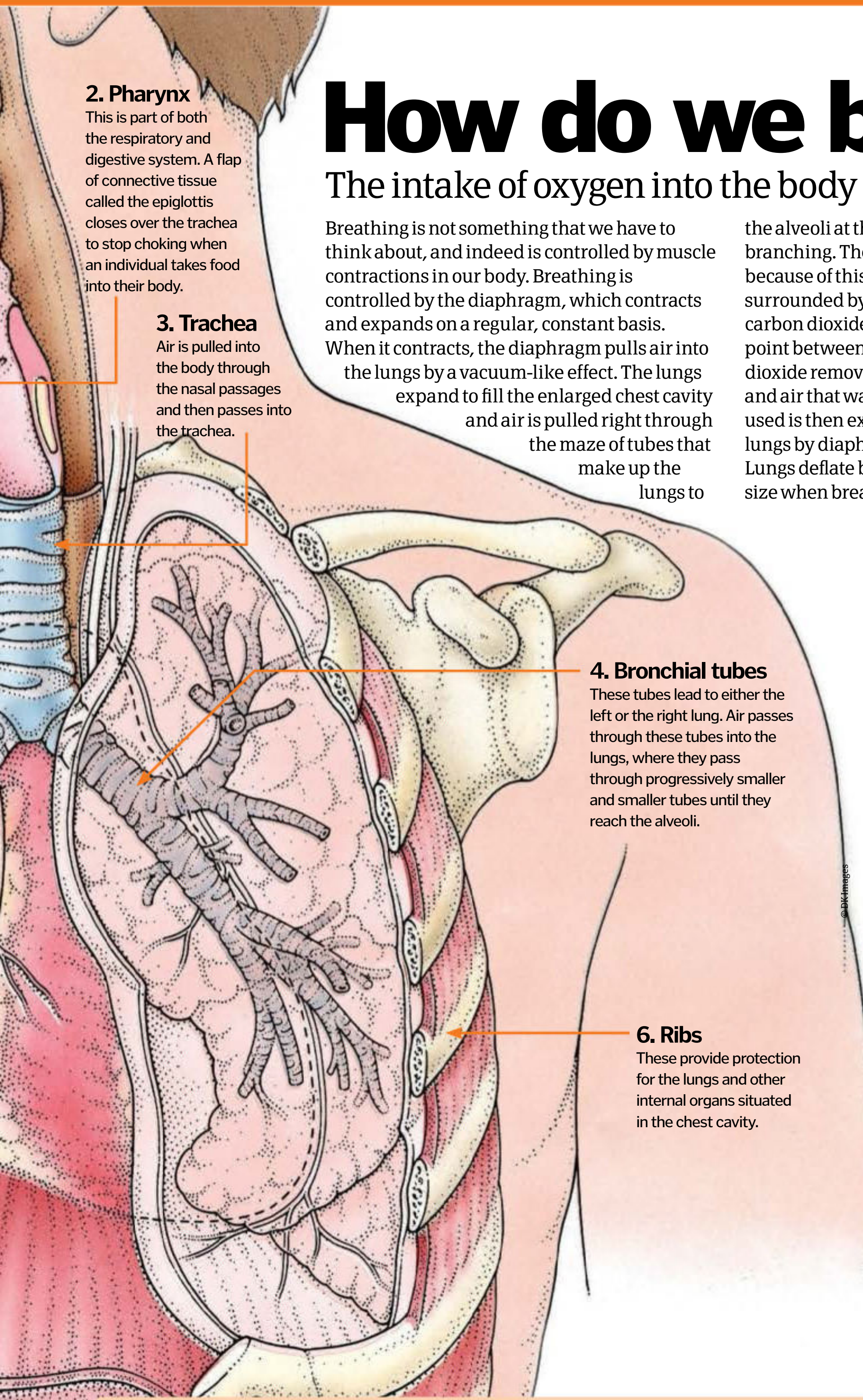
How our lungs work

Lungs are the major respiratory organ in humans

How do we breathe?

The intake of oxygen into the body is complex

Breathing is not something that we have to think about, and indeed is controlled by muscle contractions in our body. Breathing is controlled by the diaphragm, which contracts and expands on a regular, constant basis. When it contracts, the diaphragm pulls air into the lungs by a vacuum-like effect. The lungs expand to fill the enlarged chest cavity and air is pulled right through the maze of tubes that make up the lungs to the alveoli at the ends, which are the final branching. The chest will be seen to rise because of this lung expansion. Alveoli are surrounded by blood vessels, and oxygen and carbon dioxide are then interchanged at this point between the lungs and the blood. Carbon dioxide removed from the blood stream and air that was breathed in but not used is then expelled from the lungs by diaphragm expansion. Lungs deflate back to a reduced size when breathing out.



2. Pharynx
This is part of both the respiratory and digestive system. A flap of connective tissue called the epiglottis closes over the trachea to stop choking when an individual takes food into their body.

3. Trachea
Air is pulled into the body through the nasal passages and then passes into the trachea.

4. Bronchial tubes
These tubes lead to either the left or the right lung. Air passes through these tubes into the lungs, where they pass through progressively smaller and smaller tubes until they reach the alveoli.

6. Ribs
These provide protection for the lungs and other internal organs situated in the chest cavity.

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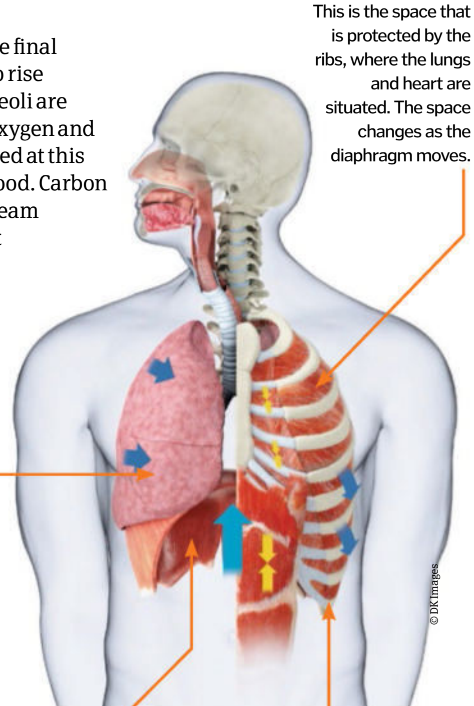

Chest cavity
This is the space that is protected by the ribs, where the lungs and heart are situated. The space changes as the diaphragm moves.

Lungs
Deoxygenated blood arrives back at the lungs, where another gas exchange occurs at the alveoli. Carbon dioxide is removed and oxygen is placed back into the blood.

Diaphragm
This is a sheet of muscle situated at the bottom of the rib cage which contracts and expands to draw air into the lungs.

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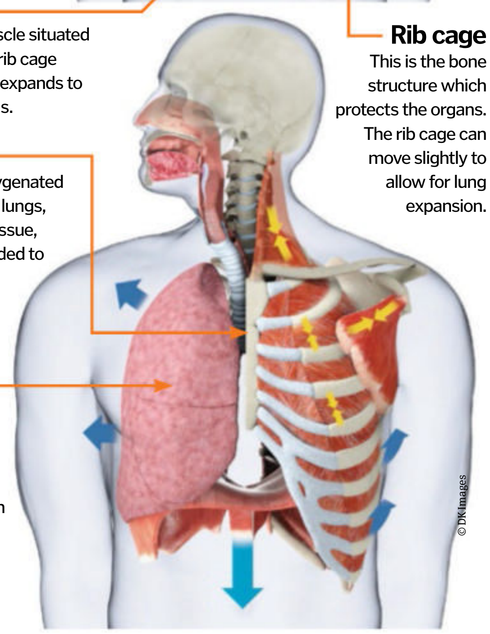


Rib cage
This is the bone structure which protects the organs. The rib cage can move slightly to allow for lung expansion.

Heart
The heart pumps oxygenated blood away from the lungs, around the body to tissue, where oxygen is needed to break down glucose into a usable form of energy.

Tissue
Oxygen arrives where energy is needed, and a gas exchange of oxygen and carbon dioxide occurs so that aerobic respiration can occur within cells.

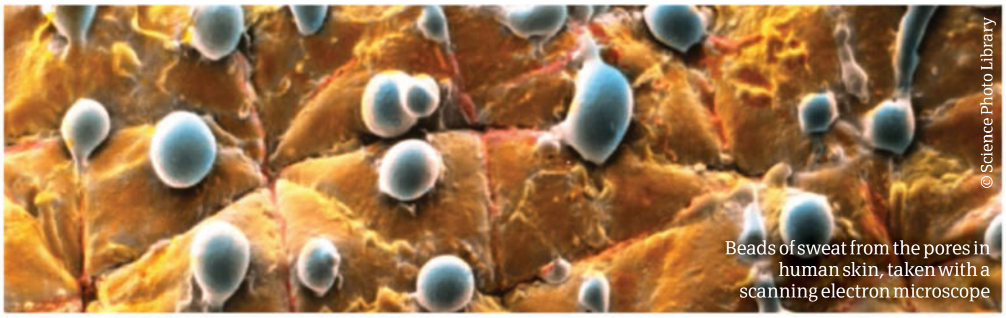
© DK Images

Why do we need oxygen?

We need oxygen to live as it is crucial for the release of energy within the body

Although we can release energy through anaerobic respiration temporarily, this method is inefficient and creates an oxygen debt that the body must repay after excess exercise or exertion has ceased. If oxygen supply is cut off for more than a few minutes, an individual will die. Oxygen is pumped around the body to be used in cells that need to break down glucose so that energy is provided for the tissue. The equation that illustrates this is:

$$C_6H_{12}O_6 + 6O_2 = 6CO_2 + 6H_2O + \text{energy}$$



Beads of sweat from the pores in human skin, taken with a scanning electron microscope

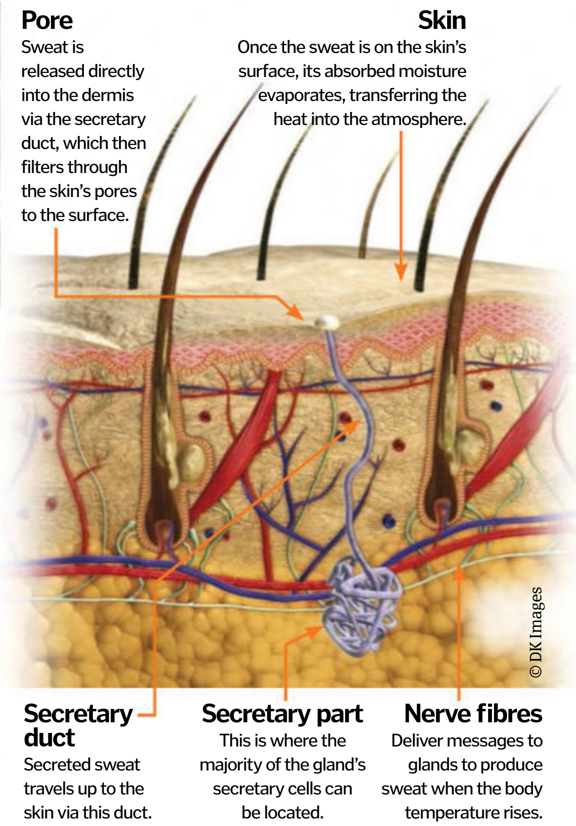
Why do we sweat?

As your doctor may tell you, it's glandular...

Sweat is produced by dedicated sweat glands, and is a mechanism used primarily by the body to reduce its internal temperature. There are two types of sweat gland in the human body, the eccrine gland and the apocrine gland. The former regulates body temperature, and is the primary source of excreted sweat, with the latter only secreting under emotional stresses, rather than those involved with body dehydration.

Eccrine sweat glands are controlled by the sympathetic nervous system and, when the internal temperature of the body rises, they secrete a salty, water-based substance to the skin's surface. This liquid then cools the skin and the body through evaporation, storing and then transferring excess heat into the atmosphere.

Both the eccrine and apocrine sweat glands only appear in mammals and, if active over the majority of the animal's body, act as the primary thermoregulatory device. Certain mammals such as dogs, cats and sheep only have eccrine glands in specific areas – such as paws and lips – warranting the need to pant to control their temperature.



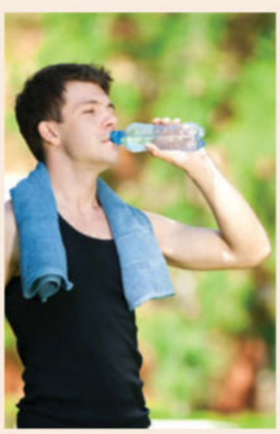
Dehydration

What happens if we don't drink enough?

Just by breathing, sweating and urinating, the average person loses ten cups of water a day. With H2O making up as much as 75 per cent of our body, dehydration is a frequent risk. Water is integral in maintaining our systems and it performs limitless functions.

Essentially, dehydration strikes when your body takes in less fluid than it loses. The mineral balance in your body becomes upset with salt and sugar levels going haywire. Enzymatic activity is slowed, toxins accumulate more easily and your breathing can even become more difficult as the lungs are having to work harder.

Babies and the elderly are most susceptible as their bodies are not as resilient as others. It has been recommended to have eight glasses of water or two litres a day. More recent research is undecided as to how much is exactly needed.

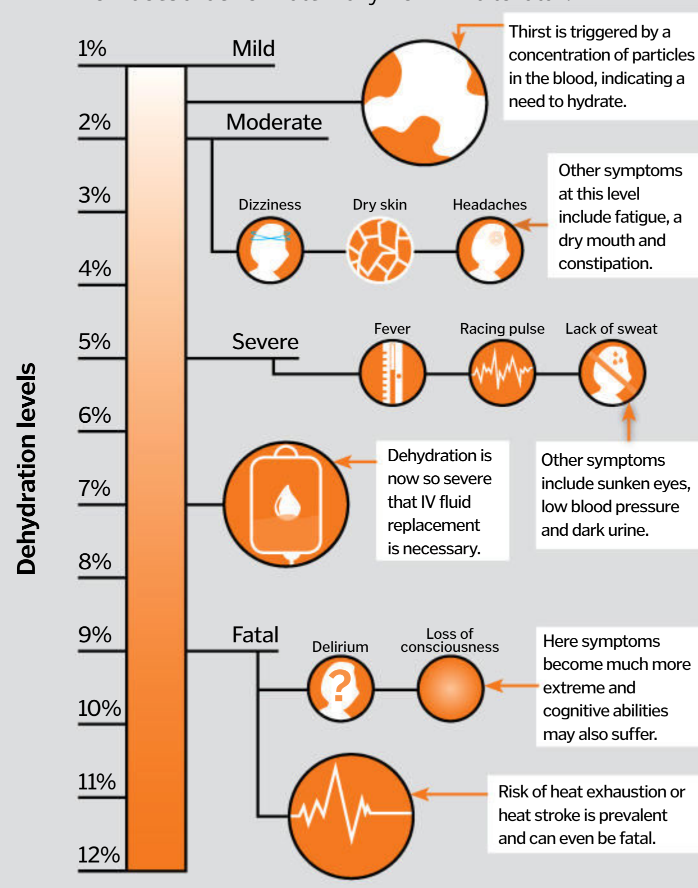


Too much H_2O?

Hydration is all about finding the perfect balance. Too much hydration can be harmful as well as too little; this is known as water intoxication. If too much liquid is in your body, nutrients such as electrolytes and sodium are diluted and the body suffers. Your cells bloat and expand and can even burst, and it can be fatal if untreated. The best treatment is to take on IV fluids containing electrolytes.

Dangers of dehydration

How does a lack of water vary from mild to fatal?



Why does skin scar?

Scars are made up of the same proteins as normal skin, so why do they look so different?

Scars are a natural part of the healing process, with most of us having some form of them on our body. The reason why scars look different compared to normal skin stems from their proteins' composition.

Normal skin benefits from a weaved protein structure, whereas the proteins in scars are aligned in one direction. This results in a different appearance compared to normal, healthy skin. Scars are smoother due to a lack of sweat glands and hair follicles, so they can often become itchy. There are also a number of different types of scar that can form. The most common is a flat scar – these tend to initially be dark and raised, but will fade and flatten over time as the scar matures. A hypertrophic scar can be identified by its red appearance and elevated nature. This scar type typically forms when the dermis is damaged, and this can become itchy and painful over time.

Keloid scars are by far the most extreme scar type when compared to the others. Unlike most scars, they extend beyond the confines of the original injury and are formed due to excessive scar tissue being produced. Keloid scars are raised above the surrounding skin, and are hard, shiny and hairless. The reason behind why keloids form is poorly understood, but it is known that people with darker skin tones are more likely to form keloids.

Pitted scars are generally formed from acne or chicken pox, and tend to be numerous in areas where these conditions were prevalent. Scar contractures, meanwhile, usually form after a burn, and are caused by the skin shrinking and tightening. The severity of these kinds of scars can depend on their bodily location; if they form around a joint they can lead to movement being restricted.

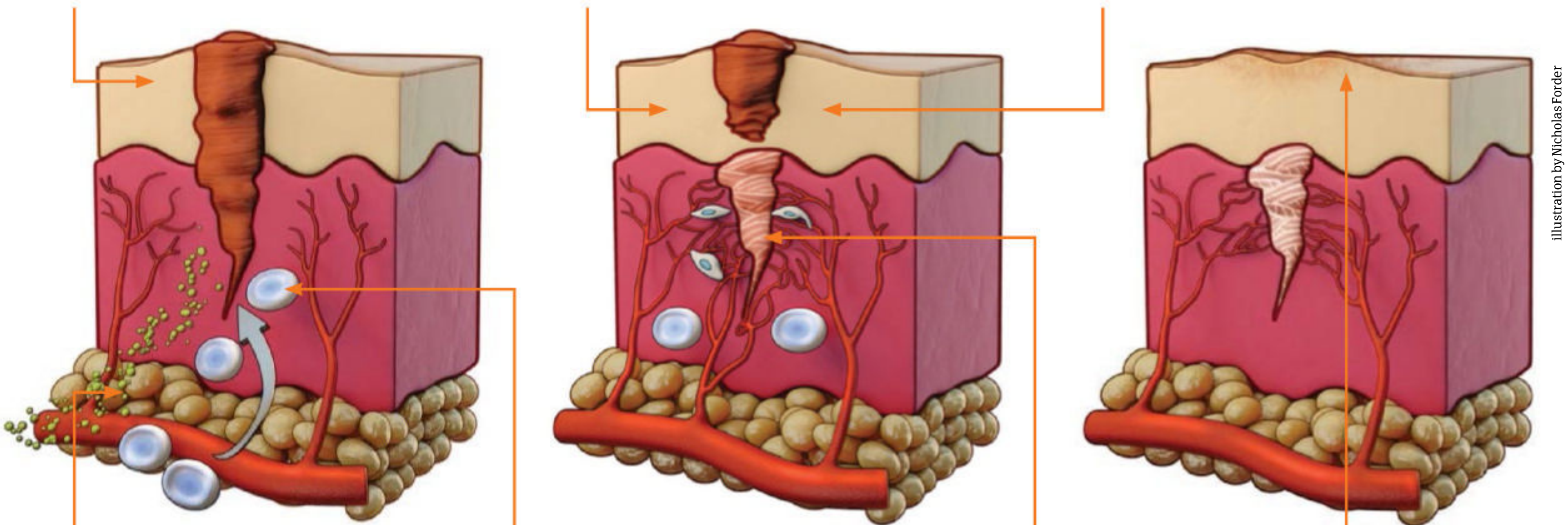
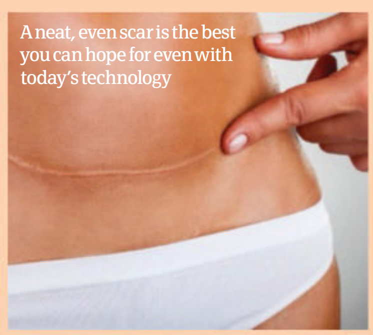


illustration by Nicholas Forder

Can scars be treated?

Scars cannot be stopped from forming, but there are various treatments available to help reduce their appearance. Silicone gels or sheets have been shown to effectively minimise scar formation and are often used when people have been burnt. These must be applied or worn throughout the scar's maturation phase to maximise their efficacy. Corticosteroid injections can be used to reduce any inflammation (swelling) around the scar and to flatten it as well. A riskier treatment for scars is surgery. This can be used to change the shape of the scar, however there is a risk of worsened scarring if unsuccessful.

There are also certain steps that can be taken to help reduce the risk of an unsightly scar forming from an injury. By cleaning dirt and dead tissue away from the wound, you are increasing the chance that the scar will form neatly. It is also vital that you don't pick or scratch the scar, as this will slow down its formation, resulting in a more obvious appearance.



A neat, even scar is the best you can hope for even with today's technology

How your immune system works

Physical defences

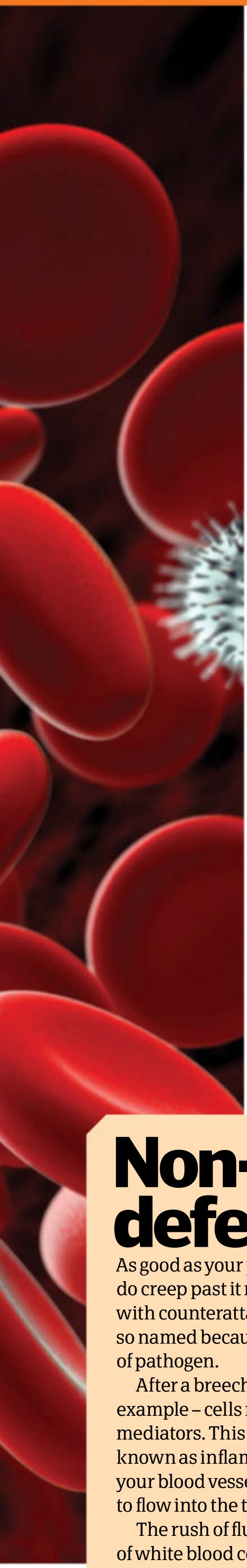
Human anatomy subscribes to the notion that good fences make good neighbours. Your skin, made up of tightly packed cells and an antibacterial oil coating, keeps most pathogens from ever setting foot in body. Your body's openings are well-fortified too. Pathogens that you inhale face a wall of mucus-covered membranes in your respiratory tract, optimised to trap germs. Pathogens that you digest end up soaking in a bath of potent stomach acid. Tears flush pathogens out of your eyes, dousing bacteria with a harsh enzyme for good measure.

Your body is locked in a constant war against a viscous army

It's true: while you're sitting around watching TV, trillions of foreign invaders are launching a full scale assault on the trillions of cells that constitute 'you'. Collectively known as pathogens, these attackers include bacteria, single-celled creatures that live to eat and reproduce; protists, larger single-cell organisms; viruses, packets of genetic information that take over host cells and replicate inside them; and fungi, a type of plant life.

Bacteria and viruses are by far the very worst offenders. Dangerous bacteria release toxins in the body that cause diseases such as E. coli, anthrax, and the black plague. The cell damage from viruses causes measles, the flu and the common cold, among numerous other diseases.

Just about everything in our environment is teeming with these microscopic intruders... including you. The bacteria in your stomach alone outnumber all the cells in your body, ten-to-one. Yet, your scrappy microscopic soldiers usually win the day against pathogens, through a combination of sturdy barriers, brute force, and superior battlefield intelligence, collectively dubbed the immune system.



The adaptive immune system

Fighting the good fight, and white blood cells are right on the front line…

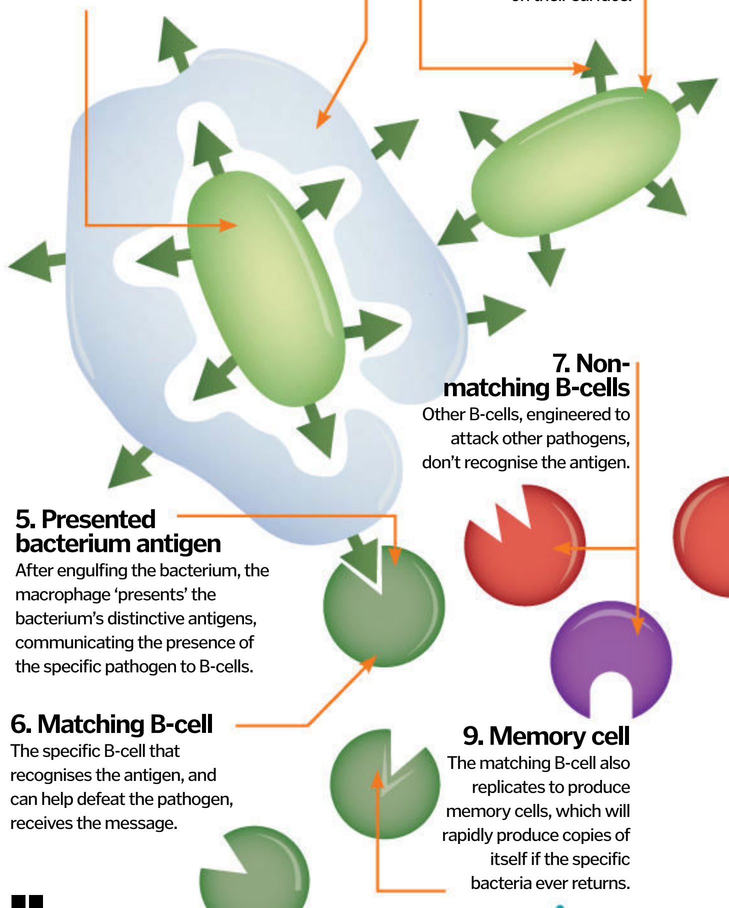
When a pathogen is tough, wily, or numerous enough to survive non-specific defences, it's up to the adaptive immune system to clean up the mess. The key forces in the adaptive immune system are white blood cells called lymphocytes. Unlike their macrophage cousins, lymphocytes are engineered to attack only one specific type of pathogen. There are two types of lymphocytes: B-cells and T-cells.

These cells join the action when macrophages pass along information about the invading pathogen, through chemical messages called interleukins. After engulfing a pathogen, a macrophage communicates details about the pathogen's antigens – telltale molecules that characterise a particular pathogen. Based on this information, the immune system identifies specific B-cells and T-cells equipped to recognise and battle the pathogen. Once they are successfully identified, these cells rapidly reproduce, assembling an army of cells that are ready and equipped to take down the attacker.

The B-cells flood your body with antibodies, molecules that either disarm a specific pathogen or bind to it, marking it as a target for other white blood cells. When T-cells find their target, they lock on and release toxic chemicals that will destroy it. T-cells are especially adept at destroying your body's cells that are infected with a virus.

This entire process takes several days to get going and may take even longer to conclude. All the while, the raging battle can make you feel terrible. Fortunately, the immune system is engineered to learn from the past. While your body is producing new B-cells and T-cells to fight the pathogens, it also produces memory cells – copies of the B-cells and T-cells, which stay in the system after the pathogen is defeated. The next time that pathogen shows up in your body, these memory cells help launch a counter-attack much more quickly. Your body can wipe out the invaders before any infection takes hold. In other words, you develop immunity.

Vaccines accomplish the same thing by giving you just enough pathogen exposure for you to develop memory cells, but not enough to make you sick.



Non-specific defences

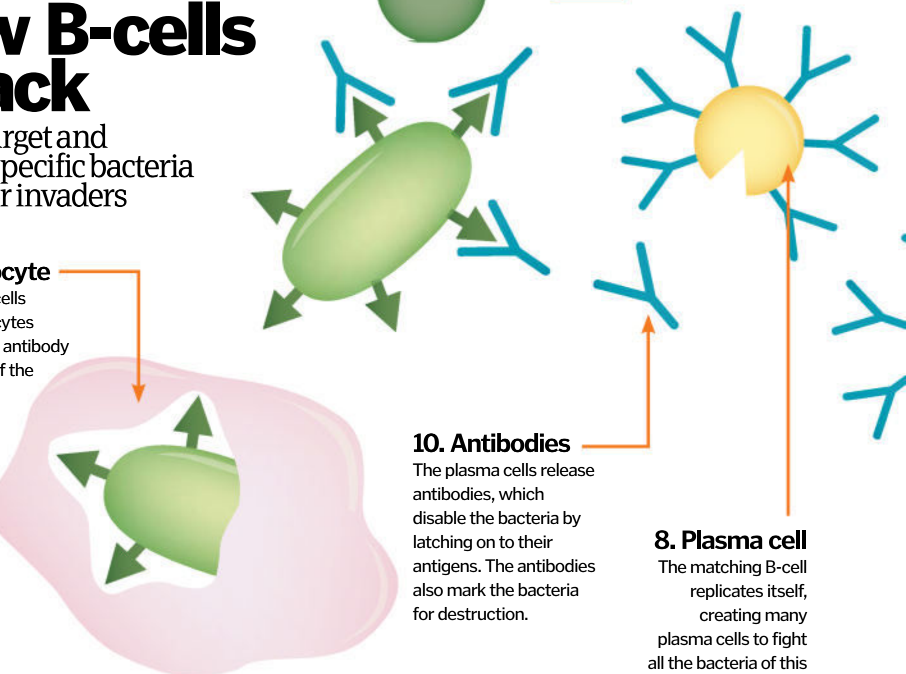
As good as your physical defence system is, pathogens do creep past it regularly. Your body initially responds with counterattacks known as non-specific defences, so named because they don't target a specific type of pathogen.

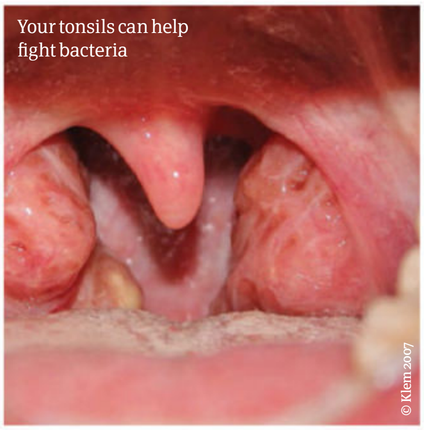
After a breech – bacteria rushing in through a cut, for example – cells release chemicals called inflammatory mediators. This triggers the chief non-specific defence, known as inflammation. Within minutes of a breach, your blood vessels dilate, allowing blood and other fluid to flow into the tissue around the cut.

The rush of fluid in inflammation carries various types of white blood cells, which get to work destroying intruders. The biggest and toughest of the bunch are macrophages, white blood cells with an insatiable appetite for foreign particles. When a macrophage detects a bacterium's telltale chemical trail, it grabs the intruder, engulfs it, takes it apart with chemical enzymes, and spits out the indigestible parts. A single macrophage can swallow up about 100 bacteria before its own digestive chemicals destroy it from within.

How B-cells attack

B-cells target and destroy specific bacteria and other invaders





Your tonsils can help fight bacteria

© Klem 2007

Disorders of the immune system

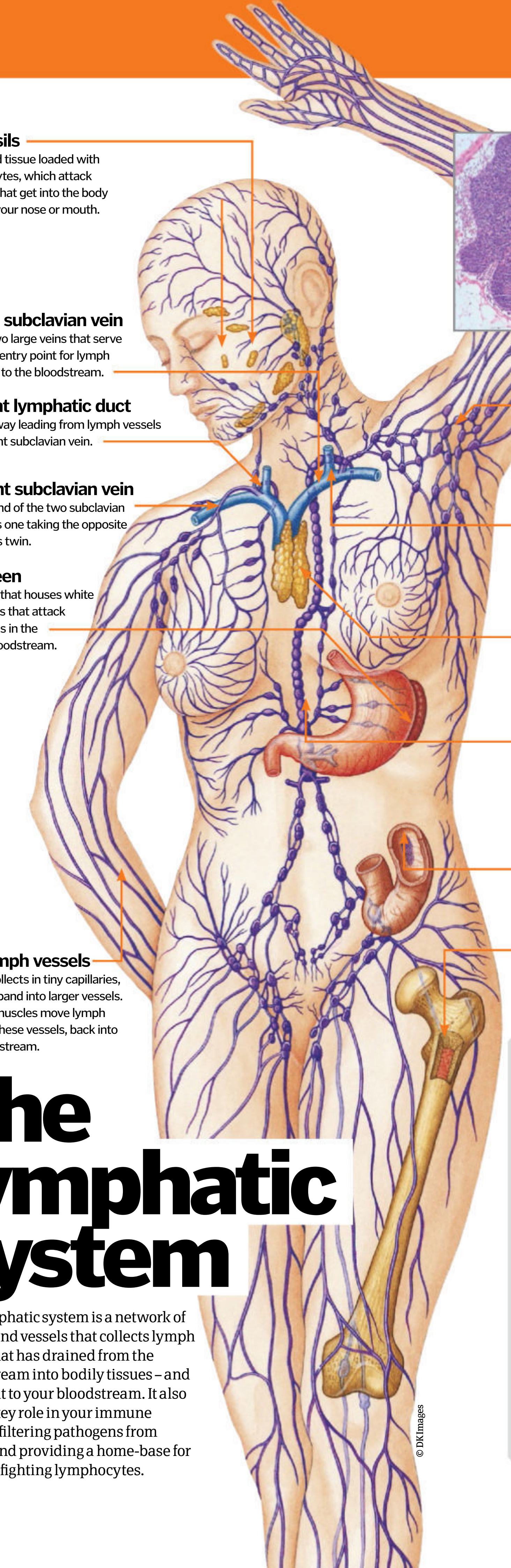
Who watches the watchmen?

The immune system is a powerful set of defences, so when it malfunctions, it can do as much harm as a disease. Allergies are the result of an overzealous immune system. In response to something relatively benign, like pollen, the immune system triggers excessive measures to expel the pathogen. On the extreme end, allergies may cause anaphylactic shock, a potentially deadly drop in blood pressure, sometimes accompanied by breathing difficulty and loss of consciousness. In autoimmune disorders such as rheumatoid arthritis, the immune system fails to recognise the body's own cells and attacks them.

In an allergic reaction, the body may resort to sneezing to expel a fairly harmless pathogen

The lymphatic system

The lymphatic system is a network of organs and vessels that collects lymph – fluid that has drained from the bloodstream into bodily tissues – and returns it to your bloodstream. It also plays a key role in your immune system, filtering pathogens from lymph and providing a home-base for disease-fighting lymphocytes.



1. Tonsils
Lymphoid tissue loaded with lymphocytes, which attack bacteria that get into the body through your nose or mouth.

2. Left subclavian vein
One of two large veins that serve as the re-entry point for lymph returning to the bloodstream.

3. Right lymphatic duct
Passageway leading from lymph vessels to the right subclavian vein.

4. Right subclavian vein
The second of the two subclavian veins, this one taking the opposite path to its twin.

5. Spleen
An organ that houses white blood cells that attack pathogens in the body's bloodstream.

6. Lymph node cluster
Located along lymph vessels throughout the body, lymph nodes filter lymph as it makes its way back into the bloodstream.

7. Left lymphatic duct
Passageway leading from lymph vessels to the left subclavian vein.

8. Thymus gland
Organ that provides area for lymphocytes produced by bone marrow to mature into specialised T-cells.

9. Thoracic duct
The largest lymph vessel in the body.

10. Lymph vessels
Lymph collects in tiny capillaries, which expand into larger vessels. Skeletal muscles move lymph through these vessels, back into the bloodstream.

11. Peyer's patch
Nodules of lymphoid tissue supporting white blood cells that battle pathogens in the intestinal tract.

12. Bone marrow
The site of all white blood cell production.

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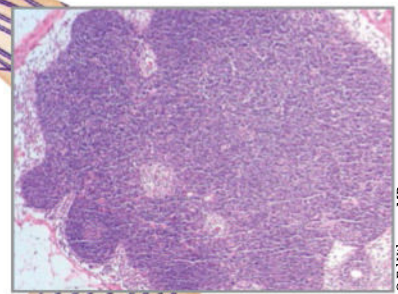


© Ed Uthman, MD

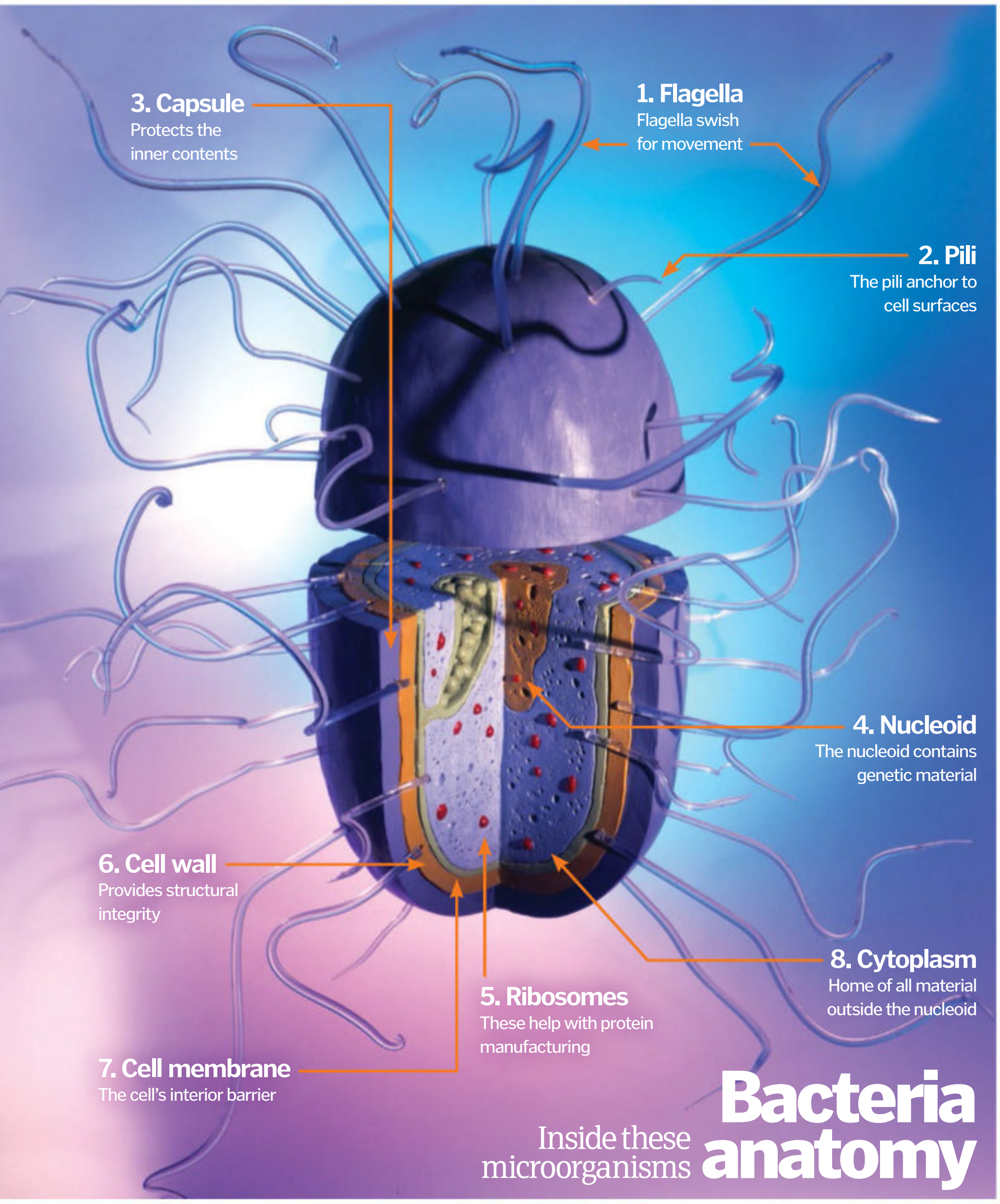
Lymph nodes explained

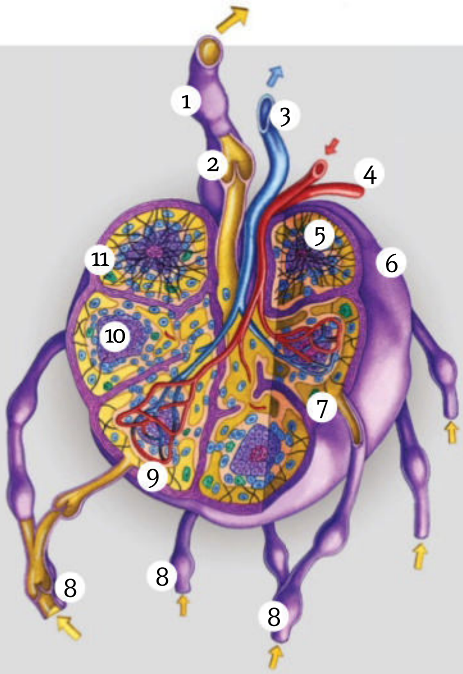
Lymph nodes filter out pathogens moving through your lymph vessels

Your immune system depends on these .04-1-inch swellings to fight all manner of pathogens. As lymph makes its way through a network of fibres in the node, white blood cells filter it, destroying any pathogens they find.

Know your enemy: Bacteria

Bacteria are the smallest and, by far, the most populous form of life on Earth. Right now, there are trillions of the single-celled creatures crawling on and in you. In fact, they constitute about four pounds of your total body weight. To the left is a look at bacteria anatomy…





Major points of the lymph node

1. Outgoing lymph vessel
The vessel that carries filtered lymph out of the lymph node

2. Valve
A structure that prevents lymph from flowing back into the lymph node

3. Vein
Passageway for blood leaving the lymph node

4. Artery
Supply of incoming blood for the lymph node

5. Reticular fibres
Divides the lymph node into individual cells

6. Capsule
The protective, shielding fibres that surround the lymph node

7. Sinus
A channel that slows the flow of lymph, giving macrophages the opportunity to destroy any detected pathogens

8. Incoming lymph vessel
A vessel that carries lymph into the lymph node

9. Lymphocyte
The T-cells, B-cells and natural killer cells that fight infection

10. Germinal centre
This is the site of lymphocyte multiplication and maturation

11. Macrophage
Large white blood cells that engulf and destroy any detected pathogens

What is HIV…

…and how does it affect the immune system?

The human immunodeficiency virus (HIV) is a retrovirus (a virus carrying ribonucleic acid, or RNA as it's known), transmitted through bodily fluids. Like other deadly viruses, HIV invades cells and multiplies rapidly inside. Specifically, HIV infects cells with CD4 molecules on their surface, which includes infection-fighting helper T-cells. HIV destroys the host cell, and the virus copies go on to infect other cells. As the virus destroys helper T-cells, it steadily weakens the immune system. If enough T-cells are lost, the body becomes highly susceptible to a range of infections, a condition known as acquired immune deficiency syndrome (AIDS).

Scanning electron micrograph of HIV-1 budding (in green) from cultured lymphocyte. This image has been coloured to highlight the most important features. Multiple round bumps on the cell surface represent sites of assembly and budding of virions.

Bone fracture healing process

Learn how your body mends broken bones

If a bone has too much pressure put on it, or is hit or landed on in a particular way, there is a chance it will break. Your body has ways of repairing these breaks, but it takes time and care. There are different kinds of break, ranging from a hairline fracture to a fully shattered bone, but they all mend in a similar way.

As a bone breaks, the blood vessels are also severed. Blood leaks out and forms a clot called a fracture haematoma. This stops blood flow to the area and also helps keep both pieces of bone aligned, ready for healing.

The body then makes fibrous cells and cartilage, which reinforce the bond and strengthen it. This creates a callus, which is essentially a weakened bone. Over time, the callus builds up and the two parts of the bone gradually fuse together, like a bridge being constructed from either side of a river until both ends meet in the middle.

Once both sections of bone are connected again, specialised cells called osteoblasts enter to produce bone cells. These new cells replace the callus, returning the bone to its original shape.

Much like repairing a broken toy with glue, the bone needs to be kept straight and steady for the fusion to happen correctly. This is why doctors will put a cast on the broken bone. The cast provides essential support, protection and stability, ensuring the broken bone doesn't move. A cast will generally stay on for a few weeks until the bond has become strong enough, but it could take months for a properly set bone to fully recover.

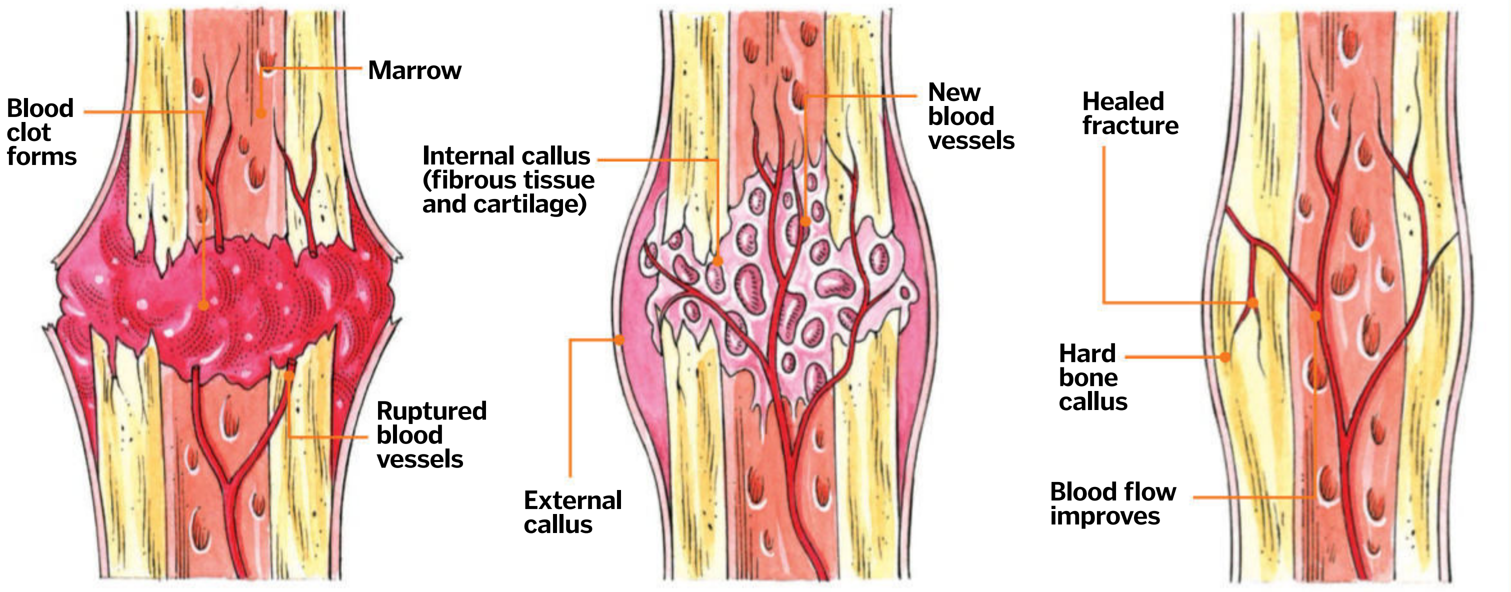
All-star cast

Most breaks on an arm or a leg will have a plaster cast put on them to prevent the bone from setting at a wonky angle or not setting at all.

It will generally be made from plaster of Paris. This is a mixture of water and gypsum that sets really hard once it has dried. The broken bone is bandaged and the wet mixture is applied to the gauze. Once it has dried then it should provide safety and stability for the bone.

Fibreglass is an increasingly common cast material. As with the plaster cast, the broken bone is bandaged up. Next, another bandage, made of fibreglass and layered with resin, is soaked in water. This makes it flexible enough to be wrapped around the bone before it hardens as it dries. This is much lighter than a plaster cast and the outer layer is waterproof.

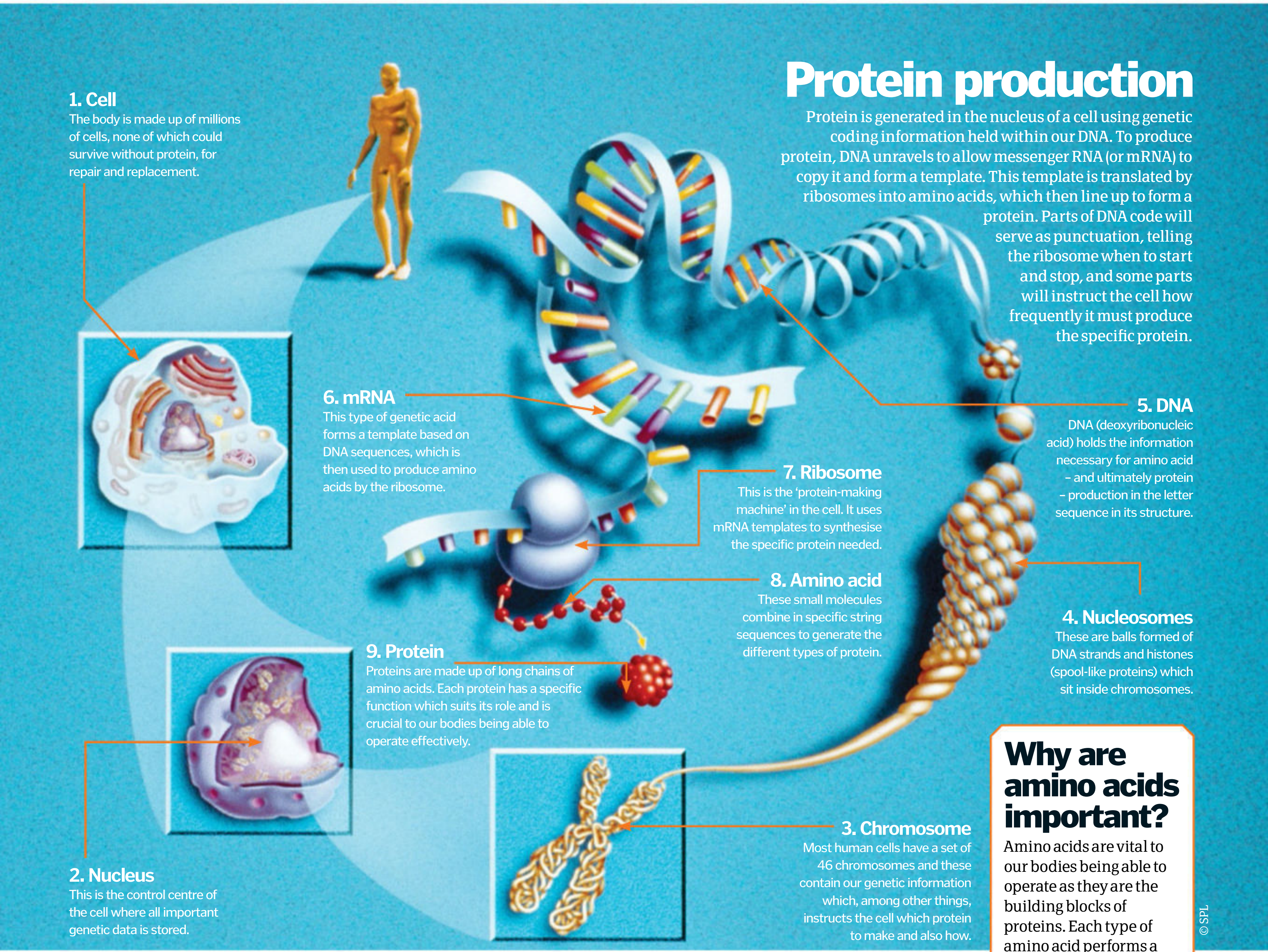
The stages of bone repair



Blood clot
When a bone breaks, the blood vessels that run through the bone are severed. The blood forms a clot to align the bones. This creates a solid yet weak structure to prepare for mending. The clot also cuts off blood flow to the edges of the broken bone, so these cells die.

Tissue growth
A few days later, the blood clot – called the fracture haematoma – is gradually replaced by tougher tissue, which becomes a soft callus. Fibrous tissue and cartilage are produced that begin to bridge the gap between the fractured ends. New blood vessels begin to form and the callus usually lasts around three weeks.

Remodelling
Bone-forming cells called osteoblasts work in teams to build a new bone, creating a more solid structure called a hard bone callus. It takes several months to fill the cavity with harder bone, strengthened by nutrients like calcium and phosphorus. However, it may take longer for the bone to be completely healed.



How do we make protein?

Proteins are the building blocks of the human body, but how do we go about manufacturing them?

Proteins are large complex molecules made up of a chain of amino acids. Every cell in our body needs protein to stay alive as it is necessary for tissue repair and replacing dead cells.

They have many other functions as well as aiding cell repair and production including forming antibodies to help fight off disease, forming enzymes which speed up or trigger chemical reactions and co-ordinating processes within the body (via hormone regulation, for instance). Proteins also provide support for cells and form structural elements of the body, such as nails and teeth, as well as facilitating the transportation of some small molecules around various systems.

We build proteins using information encoded in our genetic code. DNA code utilises groups of three letters (a mix of A, G, C and T) and these short sequences, which are known as triplets or codons, then code mRNA templates; these templates are 'translated' by cell ribosomes into amino acids.

Each protein is made up of hundreds of thousands of amino acids, which are in long chains. There are 20 different types of amino acid that can be combined to build a protein and it is the sequence of amino acids that determines each protein's unique three-dimensional structure and its function.

However, not all amino acids can be made by the body. The ones that need to be consumed via our diet are called essential amino acids. If possible, the body will also conserve energy by using amino acids from food rather than producing them itself. Protein deficiency can cause diseases such as kwashiorkor, a form of malnutrition common in poverty-stricken areas.

Why are amino acids important?

Amino acids are vital to our bodies being able to operate as they are the building blocks of proteins. Each type of amino acid performs a different job, which aids protein activity in the body and determines the protein's primary function(s). Without these, proteins would not be able to help the body with movement, defence against disease, processing food or co-ordinating general growth and development.

There are nine essential amino acids for humans that must be absorbed from external protein sources (eg meat/fish) as they cannot be synthesised by the body. Without the required amount of amino acids, the body can really suffer.

The cell cycle

Inside one of the body's most vital processes

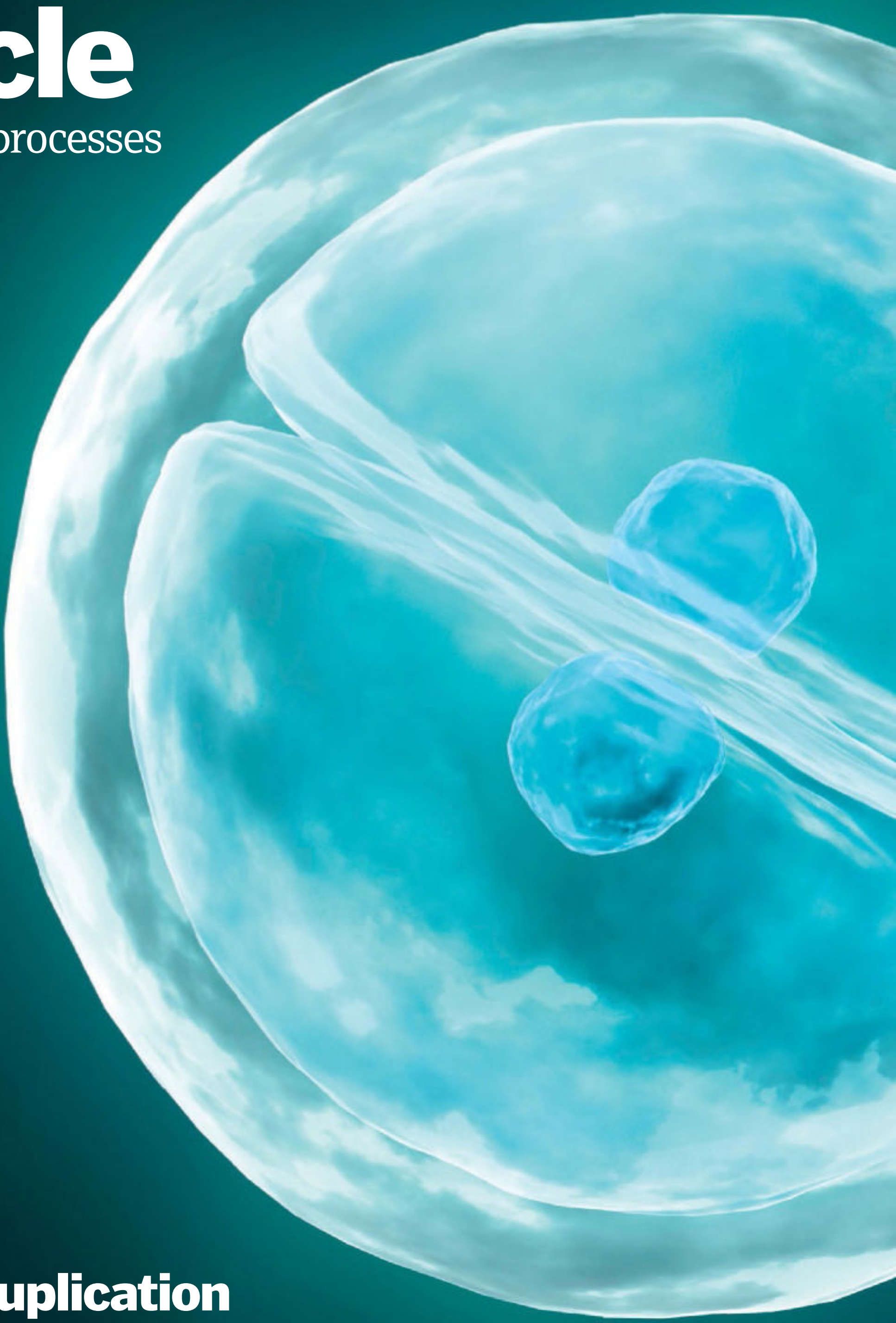
The continuous cycle of cell division and growth is essential to all life on Earth. Without it, no organism on the planet would be able to reproduce or develop. The cell cycle consists of three main stages: interphase, mitosis and cytokinesis.

During interphase, the cell expands and makes the new proteins and organelles it will need for division. It then makes copies of its chromosomes, doubling the amount of DNA in the cell and ensuring the conditions are right to begin the next phase.

In mitosis, the membrane surrounding the nucleus breaks down, exposing the chromosomes, which are pulled to opposite sides of the cell by tiny spindle fibres. A new nuclear envelope then forms around the chromosomes at each end of the cell. During cytokinesis the cytoplasm splits in half to create two 'daughter' cells, each with their own nucleus and organelles.

The cycle is managed by regulating enzymes known as CDKs . These act as a checkpoint between the phases of division, giving the signal for the next stage in the cycle to begin.

The cell cycle of prokaryotic cells (those without a nucleus) is slightly different. Bacteria and other prokaryotes divide via a process called binary fission, in which the cell duplicates its genetic material before doubling in size and splitting in two. Meiosis is another type of cell division and is concerned with sexual reproduction as opposed to the asexual organic growth of tissue in mitosis.

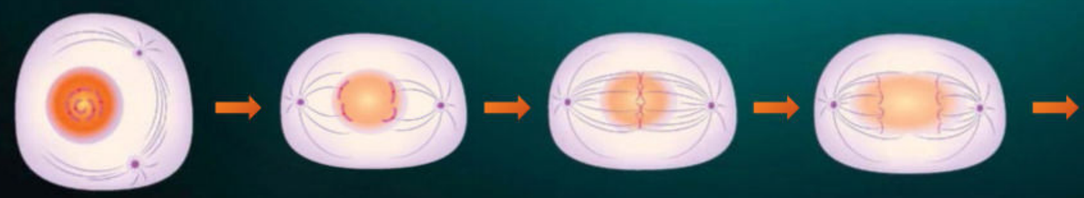


Cancer and the cycle

If the cell cycle goes wrong, cancerous tumours are a possible consequence. It all depends on the levels of proteins in the cycle. A protein called p53 halts the process if DNA is damaged. This provides time for the protein to repair the DNA as the cells are then killed off and the cycle begins anew. On the rare occasions this process fails, cells can reproduce at a rapid rate and tumours can form. Chemo- and radiotherapy work by destroying these mutated cells. A p53 mutation is the most frequent one leading to cancer. An extreme case is Li Fraumeni syndrome, where a genetic defect in p53 leads to a high frequency of cancer in those affected.

Cell duplication

Explore the key stages of mitosis now



Prophase
Chromosomes condense, becoming thicker and shorter. Sister chromatids form when the chromosomes replicate themselves.

Prometaphase
The nuclear envelope breaks down and spindle fibres extend from either side of the cell to attach to the middle of each chromatid.

Metaphase
In this phase, all the spindle fibres are attached and the chromosomes are arranged in a line along the equator of the cell.

Anaphase
Now, the spindle fibres pull the chromosomes apart, with the chromatids moving to opposite ends or 'poles' of the cell.

Every step of the cell division cycle is vital for life as we know it

An expert's view

Paul Nurse, Nobel Prize winner and director of the Francis Crick Institute, chats about cell cycle

What is the cell cycle?
The cell is the basic unit of life for all living things. One of its many properties is the ability to reproduce. The cell cycle is a series of processes that occur between the birth of the cell and its division into two.

What is mitosis?
Mitosis describes what happens near the end of the cycle. The replicated chromosomes are separated from each other into opposite ends of the cell just before the cell divides.

What are the different parts of the cycle?
The other major part occurs before mitosis and is the process in which the DNA that makes up the chromosomes replicates itself. This is called the S-phase or DNA synthetic phase [which is part of interphase]. The S-phase replicates and mitosis separates and divides.

What is the difference between mitosis and meiosis and does cell division occur in both?
Meiosis is usually considered to be the mitotic full cycle and also leads towards cell reproduction. However, in meiosis there are two M-phases or divisions so the number of DNA and chromosomes are halved. Meiosis uses gametes for fertilisation in diploid cells in animal and plants.

Does it occur in eukaryotic or prokaryotic cells?
Only in eukaryotic cells. In prokaryotic cells there is a cell cycle but it is not mitosis. This [process] is simply the copying of DNA and then a much less obvious separation of the copied DNA into the two divided cells.

Why did you use yeast in your experiments?
Yeast is a very simple eukaryote, which reproduces in much the same way as more complex cells in us. It only has 5,000 genes compared to our 25,000. It simplifies cell division so is extremely convenient to study. It's got fantastic genetics and genomics, which allow you to investigate complicated processes like the cell cycle.

Why do skin cells divide so quickly and nerve cells so slowly?
Cells change at varying rates and some nerve cells barely divide at all. This is one reason why it is difficult to regenerate the nervous system when it becomes damaged. Because the body has to deal with cuts and abrasions, it is much easier to get skin cells to divide.

What is tissue culture and why is it important?
It is simply a way of growing cells from animals and plants in test tubes. They will divide under these circumstances so you can study the cell cycle away from the complexities of an animal or plant.

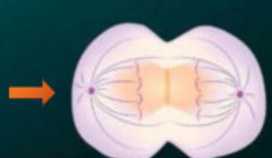
What are the differences between plant and animal cell cycles?
Fundamentally, not very much. They both undergo the same processes but are subject to different overall controls.

What is proteolysis and how does that mechanism help the cell cycle?
It is a biochemical mechanism that breaks down protein. It takes away certain proteins as part of a regulatory system for a variety of biological process such as the cell cycle. It is used at the end of the cycle to destroy excess protein and prepare for the next cycle.

You discovered CDK (Cyclin-dependent kinase). How do they contribute to the cell cycle?
CDK is a type of enzyme and my research group was involved in discovering that they were the major regulators in the cycle. CDK brings about the S-phase and mitosis and controls them.

How can the cycle help understand potential cures for cancer?
To understand cancer, you have to be able to understand the cell cycle. Crudely blocking the cell cycle is a problem as a therapy as our body is full of other cells that have to divide.

Paul Nurse is also the former director of Cancer Research UK and president of the Royal Society



Telophase
The two new sets of chromosomes form groups at each pole and a new envelope forms around each as the spindle disappears.

Cytokinesis
The cytoplasm divides and two or more daughter cells are produced. Mitosis and the cell cycle have now reached their end.

Human pregnancy

Nine months of change and growth

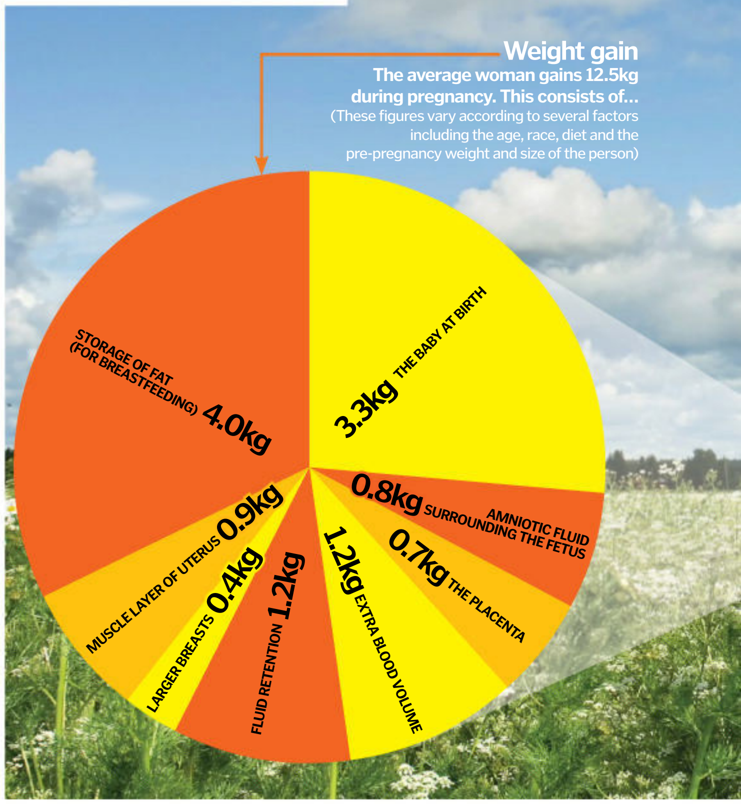
Pregnancy is a unique period in a woman's life that brings about physical and emotional changes. When it occurs, there is an intricate change in the balance of the oestrogen and progesterone hormones, which causes the cessation of menstruation and allows the conditions in the uterus (womb) to become suitable for the growth of the fetus. The lining of the uterus, rather than being discharged, thickens and enables the development of the baby.

At first, it is a collection of embryonic cells no bigger than a pinhead. By week four the embryo forms the brain, spinal cord and heart inside the newly fluid-filled amniotic sac. Protected by this cushion of fluid, it becomes recognisably human and enters the fetal stage by week eight.

Many demands are put on the mother's body and she is likely to experience sickness, tiredness, lower-back pain, heartburn, increased appetite and muscle cramps, as well as the enlargement of her breasts and stretch marks. Her blood sugar levels, heart rate and breathing also increase to cope with the growing demands of the fetus.

As the date of labour approaches, the mother feels sudden contractions known as Braxton-Hicks, and the neck of her uterus begins to soften and thin out. Meanwhile, the lungs of the fetus fill with surfactant. This substance enables the lungs to soften, making them able to inflate when it takes its first breath of air. Finally, chemical signals from the fetus trigger the uterus to go into labour.

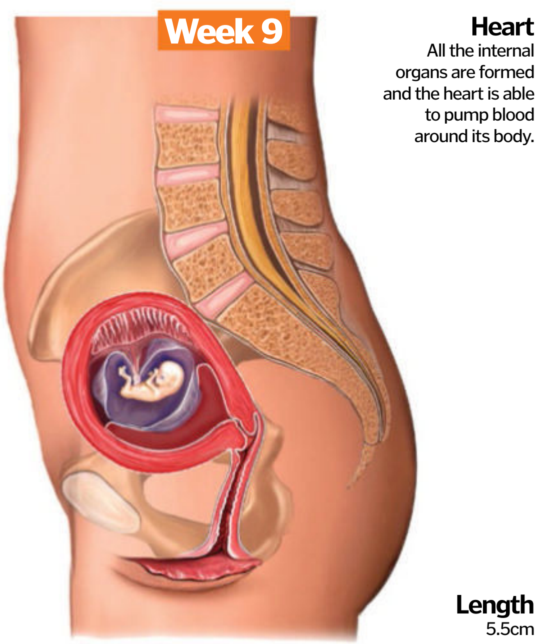
"At first, it is a collection of embryonic cells no bigger than a pinhead"



FIRST TRIMESTER (0–12 weeks)

This begins after the last menstrual period, when an egg is released and fertilised. It takes about nine weeks for the resulting embryo to develop into a fetus. During this period, the mother will be prone to sickness and mood swings due to hormonal changes.

Head
Face begins to look human and the brain is developing rapidly.



Heart
All the internal organs are formed and the heart is able to pump blood around its body.

Movement
Fetus moves around to encourage muscle development.

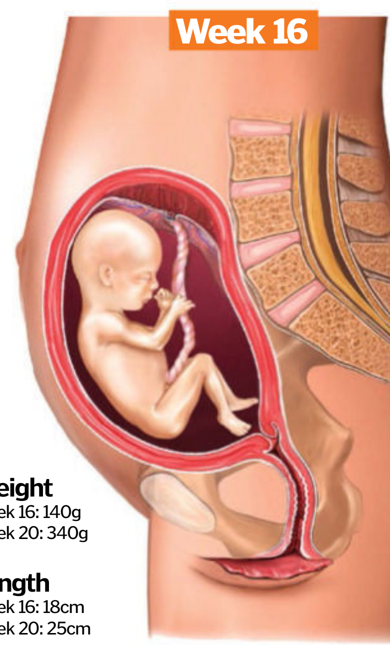
Weight
10g

Length
5.5cm

4 x trimester images © Science Photo Library

SECOND TRIMESTER (13–27 weeks)

The fetus grows rapidly and its organs mature. By week 20 its movements can be felt. At week 24 it can suck its thumb and hiccup, and can live independently of the mother with medical support.



Hair and teeth
At 16 weeks, fine hair (lanugo) grows over the fetal body. By 20 weeks, teeth start forming in the jaw and hair grows.

Movement
By week 16 the eyes can move and the whole fetus makes vigorous movements.

Sound and light
The fetus will respond to light and is able to hear sounds such as the mother's voice.

Vernix
By 20 weeks, this white, waxy substance covers the skin, protecting it from the surrounding amniotic fluid.

Sweating
An increase in blood circulation causes mother to sweat more.

Weight
Week 16: 140g
Week 20: 340g

Length
Week 16: 18cm
Week 20: 25cm

The placenta

The placenta is an essential interface between the mother and fetus. When mature it is a 22cm diameter, flat oval shape with a 2.5cm bulge in the centre. The three intertwined blood vessels from the cord radiate from the centre to the edges of the placenta. Like tree roots, these villous structures penetrate the placenta and link to 15 to 20 lobes on the maternal surface.

The five major functions of the placenta deal with respiration, nutrition, excretion of waste products, bacterial protection and the production of hormones.

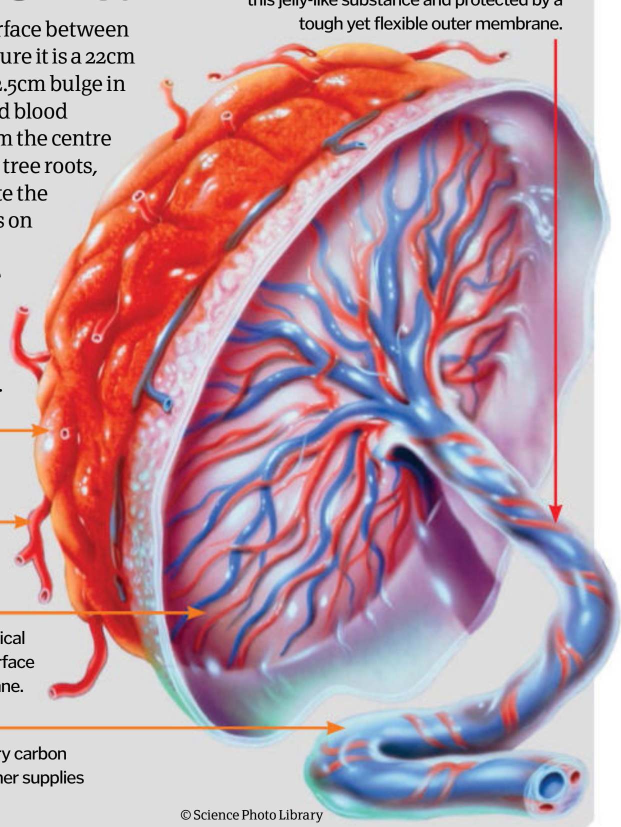
Wharton's jelly
The umbilical blood vessels are coated with this jelly-like substance and protected by a tough yet flexible outer membrane.

Placenta body
Is firmly attached to the inside of the mother's uterus.

Maternal surface
Blood from the mother is absorbed and transferred to the fetal surface.

Fetal surface
Blood vessels radiate out from the umbilical cord and penetrate the placenta. The surface is covered with the thin amnion membrane.

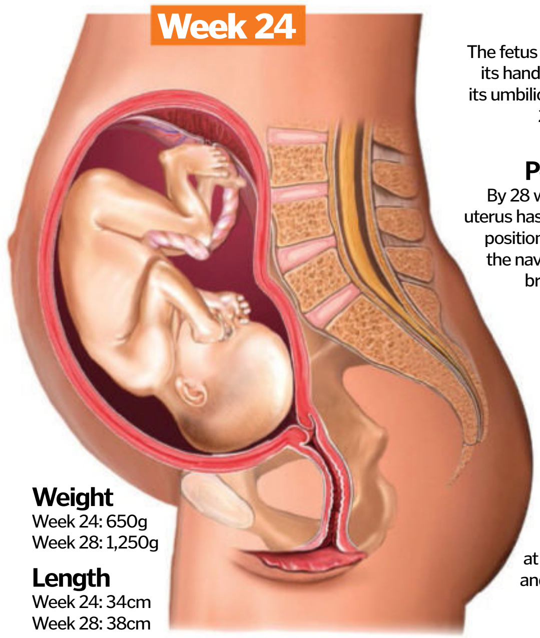
Umbilical cord
Consists of three blood vessels. Two carry carbon dioxide and waste from the fetus, the other supplies oxygen and nutrients from the mother.



THIRD TRIMESTER (28–40 weeks)

Breathlessness
The increased size of the fetus by 24 weeks causes compression of rib cage and discomfort for mother.

Movement
By the 28th week, due to less room in uterus, the fetus will wriggle if it feels uncomfortable.



Hands
The fetus can move its hands to touch its umbilical cord at 24 weeks.

Position
By 28 weeks, the uterus has risen to a position between the navel and the breastbone.

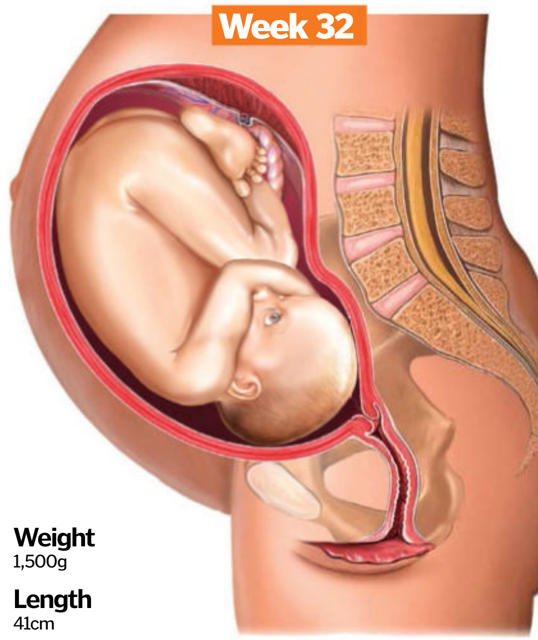
Weight
Week 24: 650g
Week 28: 1,250g

Length
Week 24: 34cm
Week 28: 38cm

Head
The head can move at 28 weeks and the eyes can open and see.

Now almost at full term, the fetus can recognise and respond to sounds and changes in light. Fat begins to be stored under the skin and the lungs are the very last organs to mature.

"The three intertwined blood vessels radiate from the centre to the edges of the plancenta"



Weight
1,500g

Length
41cm

Under pressure
Pressure on the diaphragm and other organs causes indigestion and heartburn in the mother. She will find it difficult to eat a lot.

Position
Head positions itself downwards, in preparation for labour.

Sleep patterns
Fetus will sleep and wake in 20-minute cycles.

How does an embryo develop?

Discover how a fertilised egg transforms into an embryo and eventually a new human being

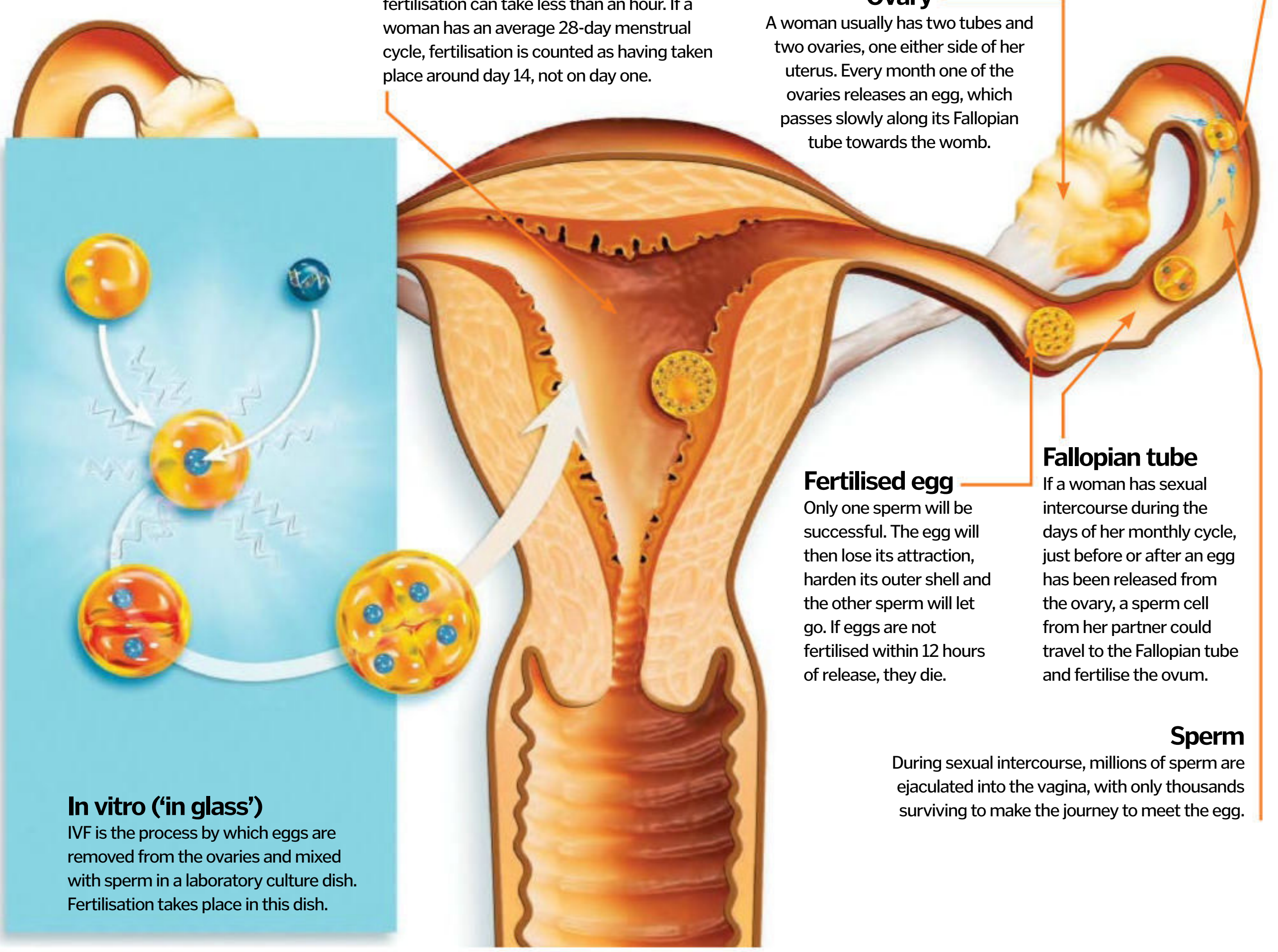
After fertilisation, the single-celled zygote splits into two, then the two cells double to four, four to eight and so on. The journey along the fallopian tube is quite slow, while growth continues. On its way, the zygote divides to make a clump of 32 cells, known as the morula stage. If the early embryo splits into two clumps before this, it may develop into identical twins. Every cell in the morula could still become part of the growing embryo.

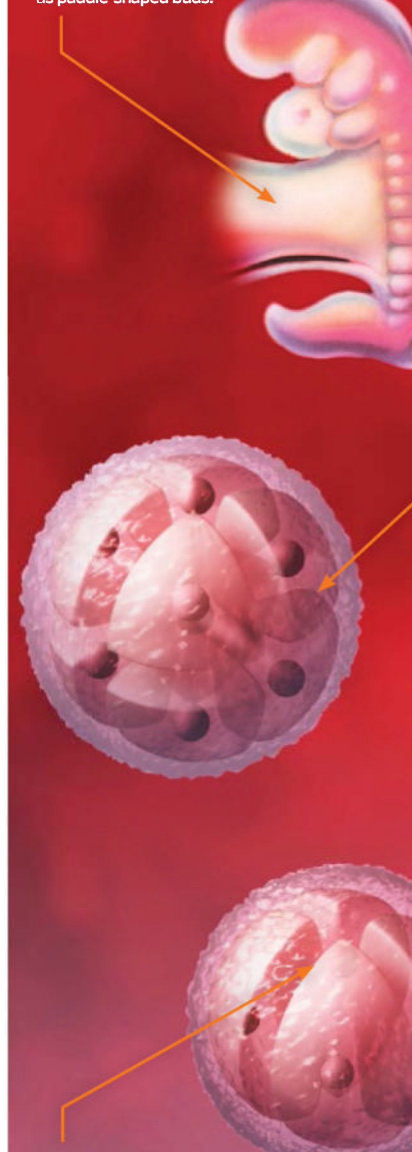
By the time the womb cavity is reached, the cell cluster becomes hollow and filled with fluid. It is now referred to as the blastocyst, which is an embryo that has reached the stage where it has two different cell types. The surface cells, or outer coat, will become, among other things, the placenta that nourishes the baby; the inner cells, known as the inner cell mass, will become the foetus itself. On contact, the blastocyst burrows into the uterine wall for nourishment in a process known as implantation. Blastocyst formation usually occurs on the fifth day after fertilisation.

The embryonic stage begins in the fifth week. From weeks five to eight, development is rapid, as major organs and systems begin to emerge. At this time, the first bone cells will also appear. By the end of the eighth week, the embryo is known as a foetus and increasingly looks like a mini human.

Fertilisation and IVF explained

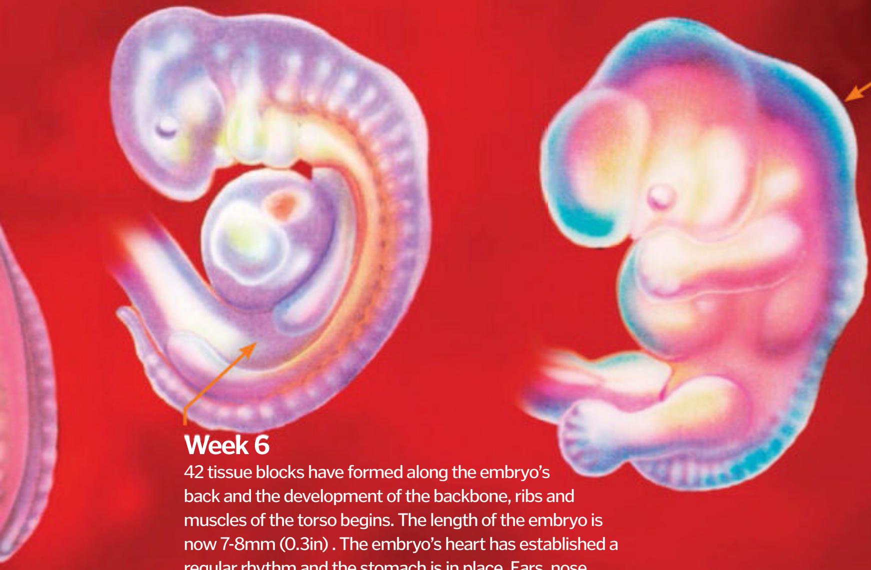
Natural fertilisation takes place via sexual intercourse. An egg, or ovum, is released by an ovary and is fertilised by a sperm. Fertilisation occurs when the sperm and egg unite in one of the female's Fallopian tubes. The fertilised egg, known as a single-celled zygote, then travels to the uterus, where it implants into the uterine lining. In vitro fertilisation (IVF) is a form of assisted reproductive technology, where the sperm nucleus is combined with an egg cell in a lab. The resultant embryo is manually introduced to the uterus, where it develops in the same way as a natural conception.





Journey of an embryo

The first eight weeks is an immense time of change for a just-conceived human



Week 7
The embryo's eyelids begin to form from a single membrane that remains fused for several days. At this stage in development, the limb muscles are beginning to form. The chest cavity will be separated from the abdominal cavity by a band of muscles; this will later develop into the diaphragm.

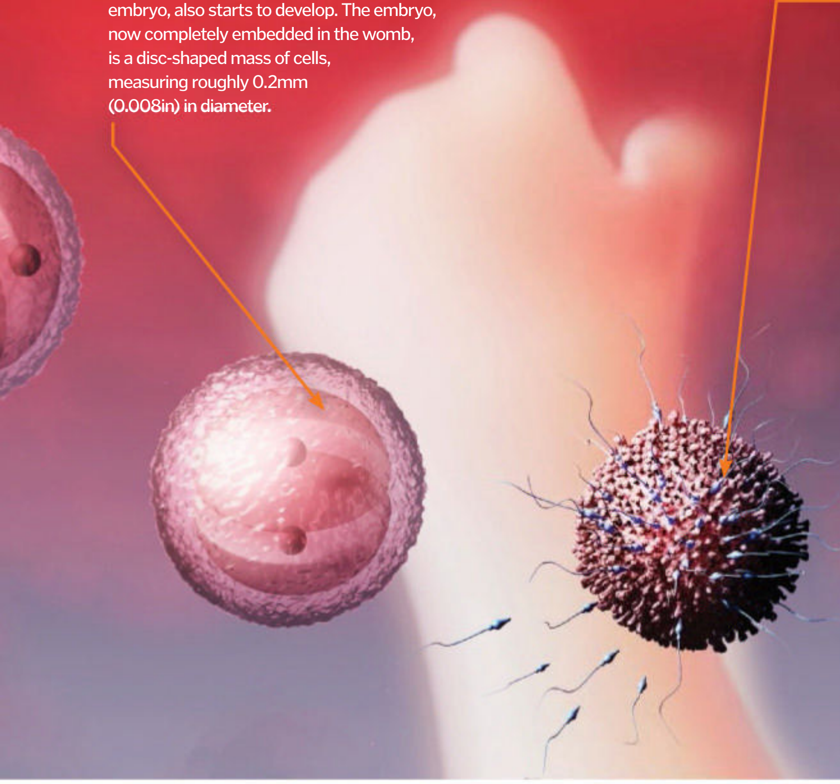
Week 8
Between the fourth and eighth weeks, the brain has grown so rapidly that the head is extremely large in proportion to the rest of the body. The gonads, or sex glands, will now start to develop into ovaries or testes. The elbows, fingers, knees and toes are really taking shape. Inside the chest cavity, the lungs are developing too. At the end of the eight-week period, the embryo becomes a foetus.

Week 6
42 tissue blocks have formed along the embryo's back and the development of the backbone, ribs and muscles of the torso begins. The length of the embryo is now 7-8mm (0.3in) . The embryo's heart has established a regular rhythm and the stomach is in place. Ears, nose, fingers and toes are just beginning to appear.

Week 4
The kidneys are forming from mesodermal tissue and the mouth is emerging. A basic spinal cord and gut now run from the head to the tail. The head and tail fold downward into a curve as a result of the embryo developing more rapidly from the front. The heart tube bends into a U shape and blood begins to circulate around the body.

Week 2
The inner cells of the embryo divide into two layers: the ectoderm and the endoderm. The tissues and organs of the body will eventually develop from these. The amniotic sac, which will soon form a protective bubble around the embryo, also starts to develop. The embryo, now completely embedded in the womb, is a disc-shaped mass of cells, measuring roughly 0.2mm (0.008in) in diameter.

Week 1
Within one week of conception, the fertilised egg, known as a blastocyst, will make its way to the uterus. Within days the cells will arrange themselves into two masses: the outer coat will become the placenta, while the inner cell mass becomes the foetus. All being well, the developing embryo will settle into the folds of the womb lining.



What is amniotic fluid?

The amniotic sac is a bag of fluid in the uterus, where the unborn baby develops. It's filled with a colourless fluid – mainly made of water – that helps to cushion the foetus and provides fluids which enable the baby to breathe and swallow. The fluid also guards against infection to either the foetus or the uterus. Amniotic fluid plays a vital role in the development of internal organs, such as the lungs and kidneys; it also maintains a constant temperature. The amniotic sac starts to form and fill with fluid within days of conception.

The body of this foetus is really taking shape, safe within the amniotic sac

The five basic human tastes

Building an in-depth map of the tongue

There is general agreement that humans have five basic tastes, although the fifth taste 'primary' has only been recently officially recognised. Sweetness, bitterness, sourness and saltiness were joined by savouriness in 2002. Other sensation are not classified as tastes.

Sweetness is associated primarily with simple carbohydrates – of which sugar is one of the most common. The way sweetness is detected is complex and only recently has the current model of multiple binding sites between the receptors and sweet substance itself been proposed and accepted. A sweet taste infers that the substance is high in energy and studies have shown that newborns in particular, who need a high calorie intake to grow, demonstrate a preference for sugar concentrations sweeter than lactose, which is found in breast milk.

Bitterness can be detected in very low levels and is generally perceived to be an unpleasant or sharp taste. Many toxic substances in nature are known to be bitter and there is an argument proposed by evolutionary scientists that bitterness sensitivity is an evolutionary defence mechanism. Humans, however, have now developed various techniques to make previous inedible bitter substances edible through reducing their toxicity, often through cooking.

The taste of saltiness is produced by the presence of sodium ions, or other closely related alkali metal ions. Potassium and lithium produce a similar taste as they are most closely related to sodium.

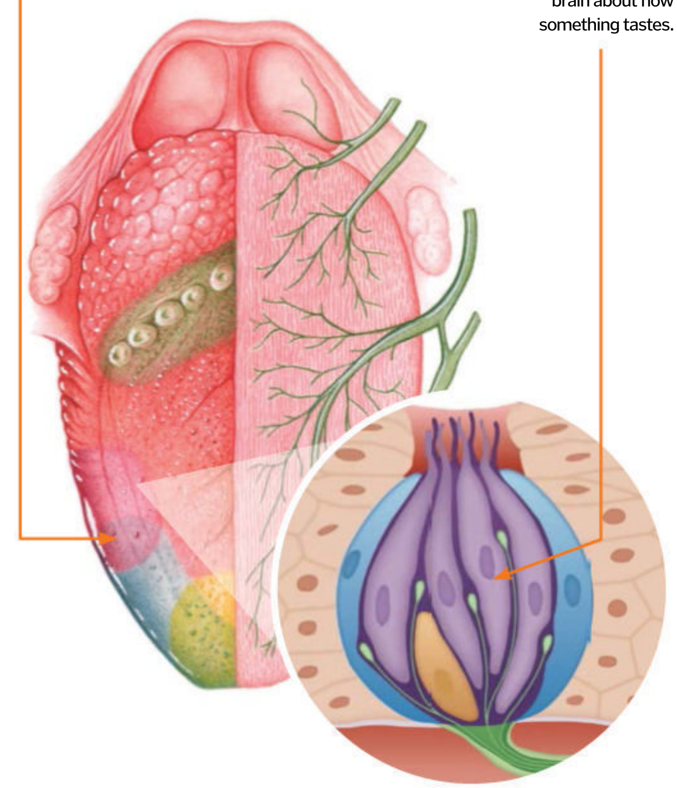
Sourness detects acidity. The way we measure the degree of sourness is through rating sour substances against dilute hydrochloric. The mechanism involved in detecting sourness is similar to saltiness in that taste is caused by a concentration of ions – in this case hydrogen ions. Savouriness is the newest of the recognised basic tastes and the taste is produced by fermented or aged foods. Glutamate is a common compound that can cause this taste and consequently savouriness is considered fundamental to Eastern cuisine.

How do taste buds work?

Discover how we distinguish between flavours

Taste buds are sensory organs that are found in the little bumps (or papillae) on the tongue. The tongue contains about 8,000 taste buds and they're replaced approximately every two weeks. Sensitive microscopic hairs on the taste buds (microvilli) pick up dissolved chemicals from food and send electrical signals to the brain that distinguishes between five different tastes: sweet, bitter, savoury (umami), salty and sour. Varying sensitivity to these tastes occurs across the whole of the tongue. But taste buds alone cannot tell us the exact flavour of food. Other factors such as smell, spiciness, temperature and texture also contribute to the eventual taste. So if you hold your nose while you eat then your brain won't get the full taste story!

"Factors such as smell, spiciness and texture also contribute to taste"



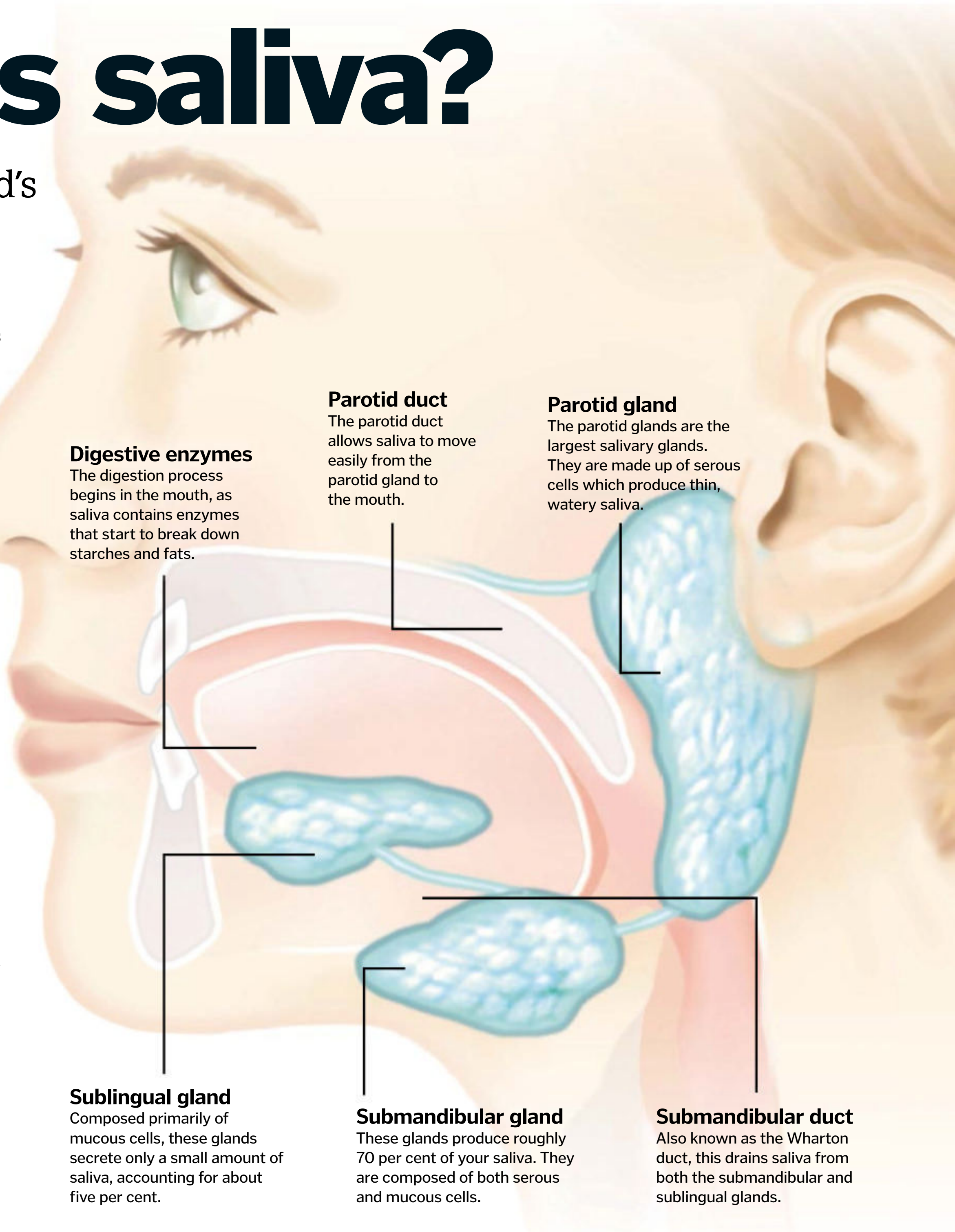
What is saliva?

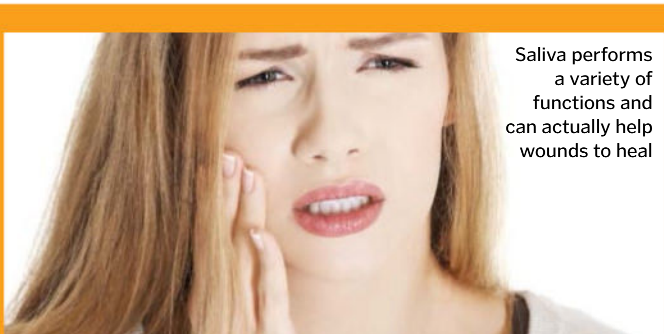
Find out this frothy liquid's vital role in maintaining human health

Humans can produce an incredible two litres (half a gallon) of saliva each day. It is made up of 99.5 per cent water, so how is it able to perform so many important functions in our mouths? The answer lies in the remaining 0.5 per cent, which contains a host of enzymes, proteins, minerals and bacterial compounds. These ingredients help to digest food and maintain oral hygiene.

As soon as food enters the mouth, saliva's enzymes start to break it down into its simpler components, while also providing lubrication to enable even the driest snack to slide easily down the throat. Saliva is also important in oral health, as it helps to protect teeth from decay and also controls bacterial levels in the mouth to reduce the risk of infection. Without sufficient saliva, tongue and lip movements are not as smooth, which, in extreme cases, can make it very difficult to speak.

With advanced scientific techniques and research, an individual's saliva can reveal a great deal of information. New studies have shown that a saliva test can be used to find out whether a person is at risk of a heart attack, as it contains C-reactive protein (CRP). This can be an indicator of heart disease when found at elevated levels in the blood. A saliva test is much less intrusive than a blood test and gives doctors a rough estimate of the health of a patient's heart. What's more, saliva contains your entire genetic blueprint. Even tiny amounts, equivalent to less than half a teardrop, can provide a workable DNA sample that can be frozen and thawed multiple times without breaking down.





Saliva performs a variety of functions and can actually help wounds to heal

Can saliva speed up healing?

Many animals do it instinctively, but it turns out that there is a benefit to humans licking their wounds. A study found that there is a compound in human saliva, namely histatin, which can speed up the healing process. Scientists conducted an experiment using epithelial cells from a volunteer's inner cheek, creating a wound in the cells so that the healing process could be monitored.

They created two dishes of cells, one that was treated with saliva and one that was left open. The scientists were astounded when after 16 hours the saliva-treated wound was almost completely closed, yet the untreated wound was still open. This demonstrated that saliva does aid the healing of at least oral wounds, something that has been suspected but unproven until this study.

Neurotransmitters and your feelings

Are our moods and emotions really just brain chemistry?

Messages are passed from one nerve cell to the next by chemical messengers called neurotransmitters. Each has a slightly different effect and by looking at what happens when neurotransmitter levels change, we are discovering that different combinations play a role in a range of complex emotions.

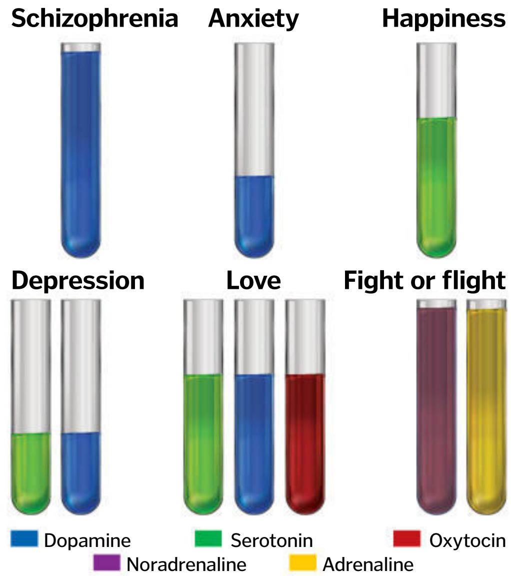
Acetylcholine excites the nerve cells that it touches, triggering more electrical activity. It plays a role in wakefulness, attention, learning and memory, and abnormally low levels are found in the brains of people with dementia caused by Alzheimer's disease.

Dopamine is a chemical that also excites nerve cells. It plays a vital role in the control of movement and posture, and low levels of dopamine underlie the muscle rigidity that exists in Parkinson's disease. Dopamine is also used in the brain's reward circuitry and is one of the chemicals responsible for the good feelings that are normally associated with more addictive behaviour types.

Noradrenaline is similar in structure to the hormone adrenaline and is involved in the 'fight or flight' response. In the brain, it keeps us alert and focussed. In contrast, GABA reduces the activity of the nerves that it interacts with and is thought to reduce feelings of fear or anxiety.

Serotonin is sometimes known as the 'happy hormone' and transmits signals involved in body temperature, sleep, mood and pain. People with depression have been found to have lower serotonin levels than normal, though raising serotonin levels with antidepressant medications does not always help.

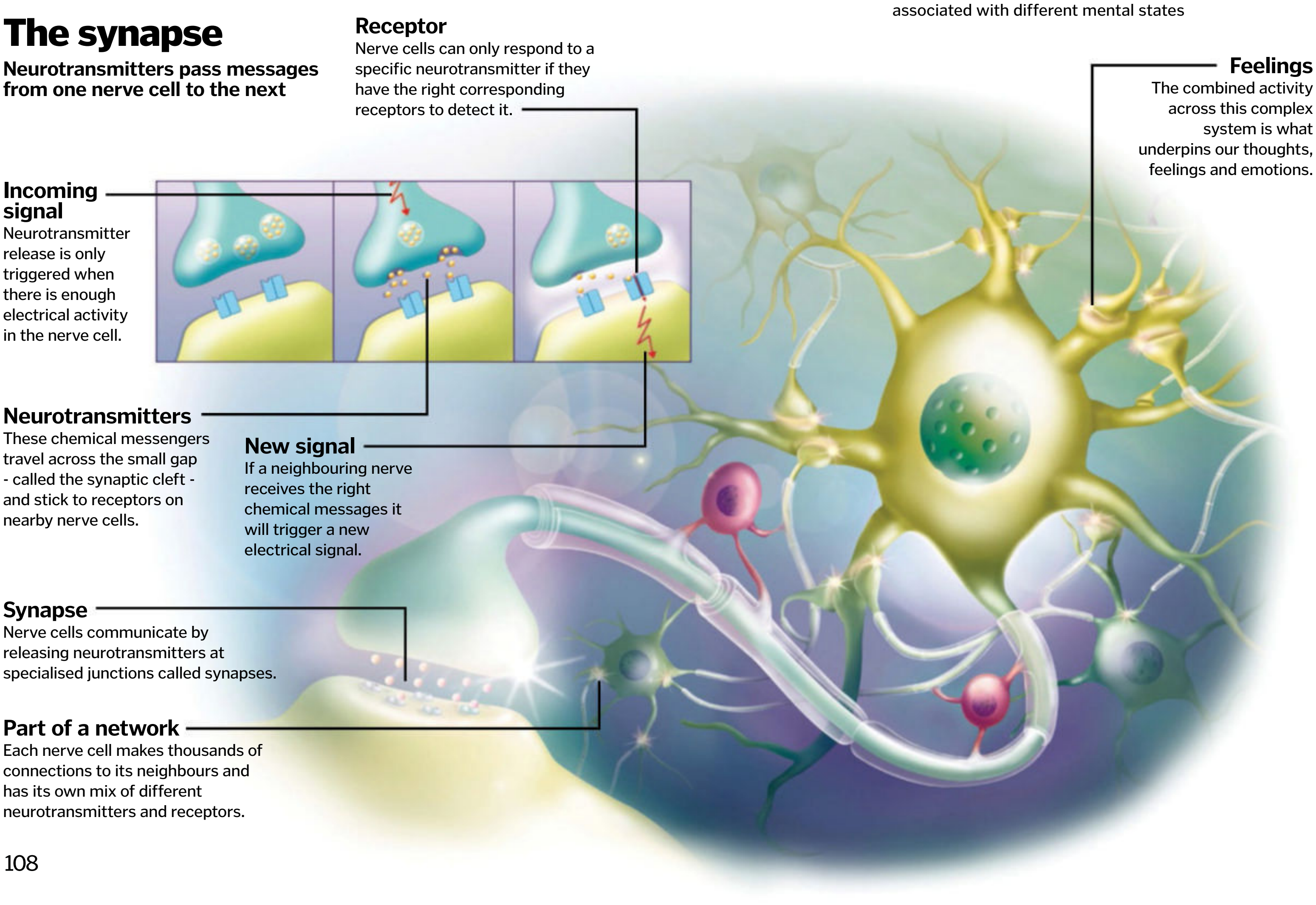
There are many more neurotransmitters in the brain and other chemicals like hormones can also influence the behaviour of nerve cells. It is these interactions that are thought to underlie the huge range of human emotions.



Different levels of neurotransmitters have been associated with different mental states

The synapse

Neurotransmitters pass messages from one nerve cell to the next



Short-term memory

Find out how the brain decides what to remember and what to forget

As you read this, you store the words at the beginning of each sentence in your short-term memory while you work your way through to the end, enabling you to understand the text. At the same time, you are probably ignoring the feeling of the glossy pages against your skin as you hold the magazine.

Short-term memory acts somewhat like a gatekeeper between incoming sensory information and long-term storage. You are constantly bombarded by information, and the incoming traces from your sensory receptors last for just fractions of a second before they are lost. You don't have time to process all of it, so short-term memory allows you to pass small amounts of important information in a temporary loop while your brain decides what to do with it.

Short-term memory has two major limitations. The first is that you can only store a small amount of information, and the second is that the memory decays over time. If you pay attention, your short-term memory can hold around four chunks of new information for between ten and 20 seconds, but if you are distracted, you will rapidly forget it all.

Rehearsing the information inside your head effectively resets the timer and restarts the memory loop, allowing you to extend this time. A part of the brain called the hippocampus then decides which bits are important enough commit to longer-term storage, and which to forget.

Extending your short-term memory

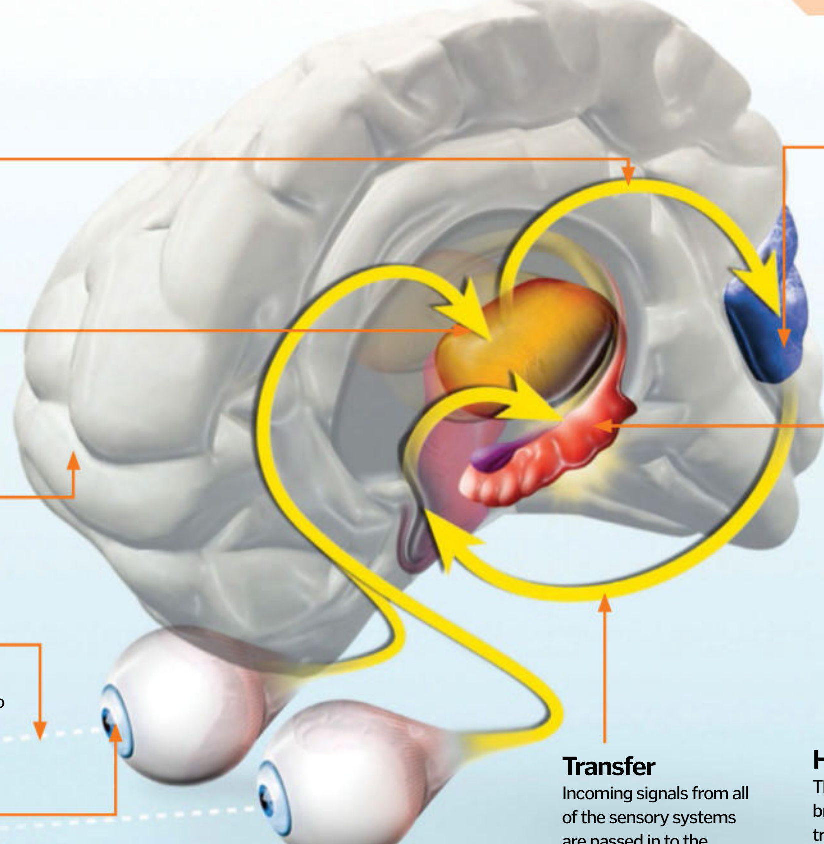
You can hold four items of information in your memory for around ten seconds without trying, but memorising a sheet of 20 words can prove challenging. Your short-term memory has its limitations, but you can improve it with a few simple tricks.

Instead of overloading your memory by trying to memorise them one-by-one, divide the images into linked chunks, for example, office objects or things that fly. Categorising the words like this helps by tapping into your long-term memory, which mainly stores linked concepts and is triggered by cues and associations.

Short-term memory tends to be encoded verbally, and you might find yourself repeating the names of the items in the pictures inside your head in order to help with recall, but you can improve still further if you take advantage of visual encoding. By creating a scene inside your head and visiting each item in turn, you start to remember the words more easily.

Making memories

Find out how incoming visual information becomes memory



Processing
The incoming signals from the eyes are passed to the occipital lobes for processing.

Thalamus
The thalamus is involved in attention and the early stages of short-term memory formation.

Prefrontal cortex
This part of the brain has a crucial role in coordinating short-term memory and in rehearsing information.

Attention
In order to transfer information from sensory memory to short-term memory you need to be paying active attention.

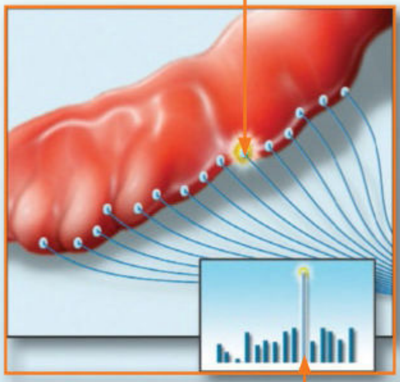
Input
Incoming information is stored for less than a second in your sensory memory.

Transfer
Incoming signals from all of the sensory systems are passed in to the hippocampus, where they are combined as a single 'experience'.

Hippocampus
This region of the brain is involved in transferring short-term memories into long-term storage.

Occipital lobe
The occipital lobes process incoming visual information.

Storage
Short-term memories are rapidly turned into long-term memories that can last days, weeks or even a lifetime.



Long-term memories
Memories are stored throughout the cortex as groups of nerve cells that fire together in coordinated patterns.

How do white blood cells work?

One of the body's main defences against infection and foreign pathogens, how do these cells protect our bodies?

White blood cells, or leukocytes, are the body's primary form of defence against disease. When the body is invaded by a pathogen of any kind, the white blood cells attack in a variety of ways; some produce antibodies, while others surround and ultimately devour the pathogens whole.

In total, there are five types of white blood cell (WBC), and each cell works in a different way to fight a variety of threats. These five cells sit in two groupings: the granulocytes and the agranulocytes. The groups are determined based on whether a cell hxas 'granules' in the cytoplasm. These granules are digestive enzymes that help break down pathogens. Neutrophils, eosinophils and basophils are all granulocytes, the enzymes in which also give them a distinct colouration which the agranulocytes do not have.

As the most common WBC, neutrophils make up between 55 and 70 per cent of the white blood cells in a normal healthy individual, with the other four types (eosinophils, basophils, monocytes and lymphocytes) making up the rest. Neutrophils are the primary responders to infection, actively moving to the site of infection following a call from mast cells after a pathogen is initially discovered. They consume bacteria and fungus that has broken through the body's barriers in a process called phagocytosis.

Lymphocytes – the second-most common kind of leukocyte – possess three types of defence cells: B cells, T cells and natural killer cells. B cells release antibodies and activate T cells, while T cells attack diseases such as viruses and tumours when directed, and regulatory T cells ensure the immune system returns to normal after an attack. Natural killer cells, meanwhile, aid T cell response by also attacking virus-infected and tumour cells, which lack a marker known as MHC.

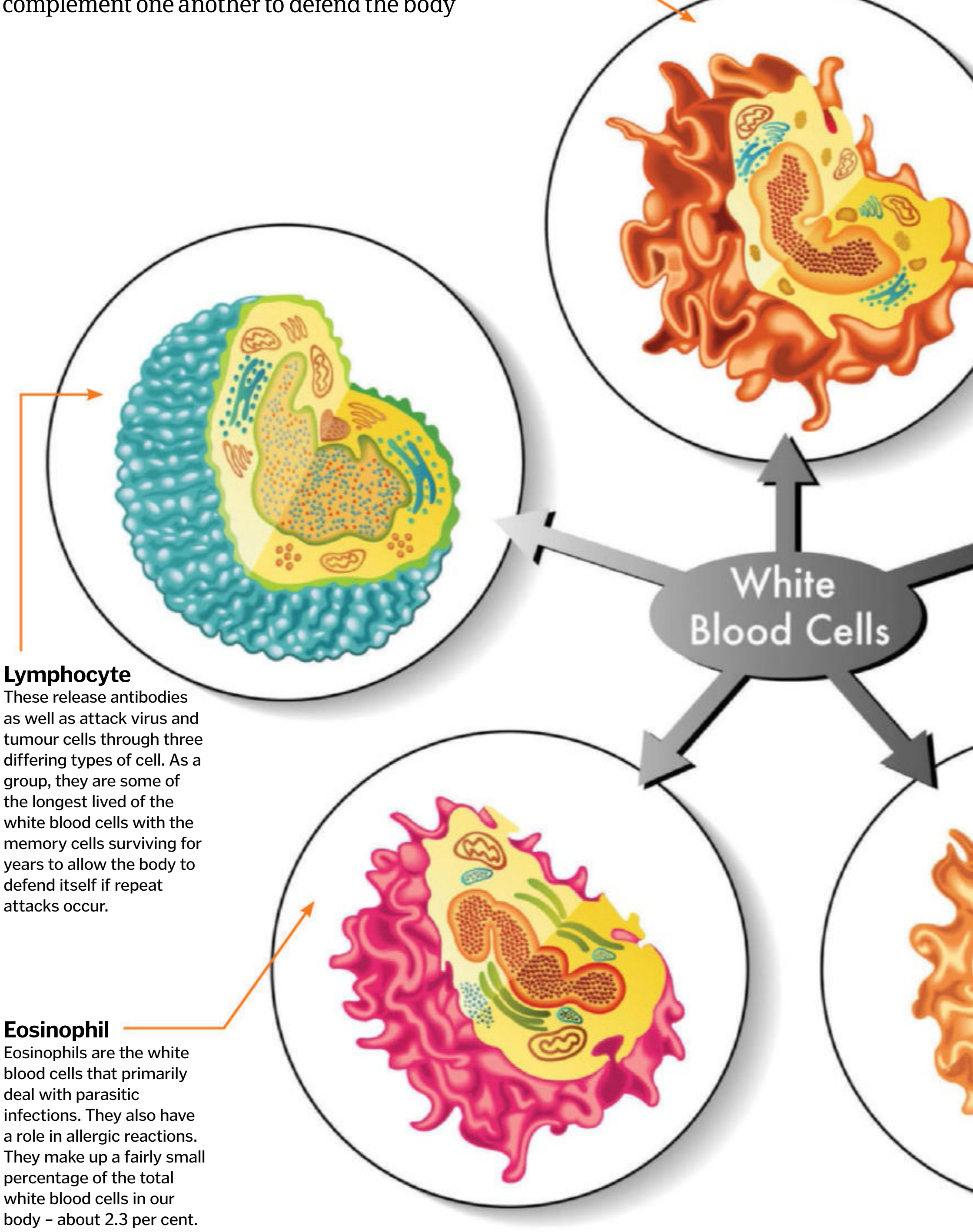
The remaining types of leukocyte release chemicals such as histamine, preparing the body for future infection, as well as attacking other causes of illness like parasites.

"Natural killer cells aid T cell response by also attacking virus-infected and tumour cells"

Types of leukocyte

Different kinds of WBC have different roles, which complement one another to defend the body

Monocyte
Monocytes help prepare us for another infection by presenting pathogens to the body, so that antibodies can be created. Later in their life, monocytes move from the bloodstream into tissue, and then evolve into macrophages which can conduct phagocytosis.

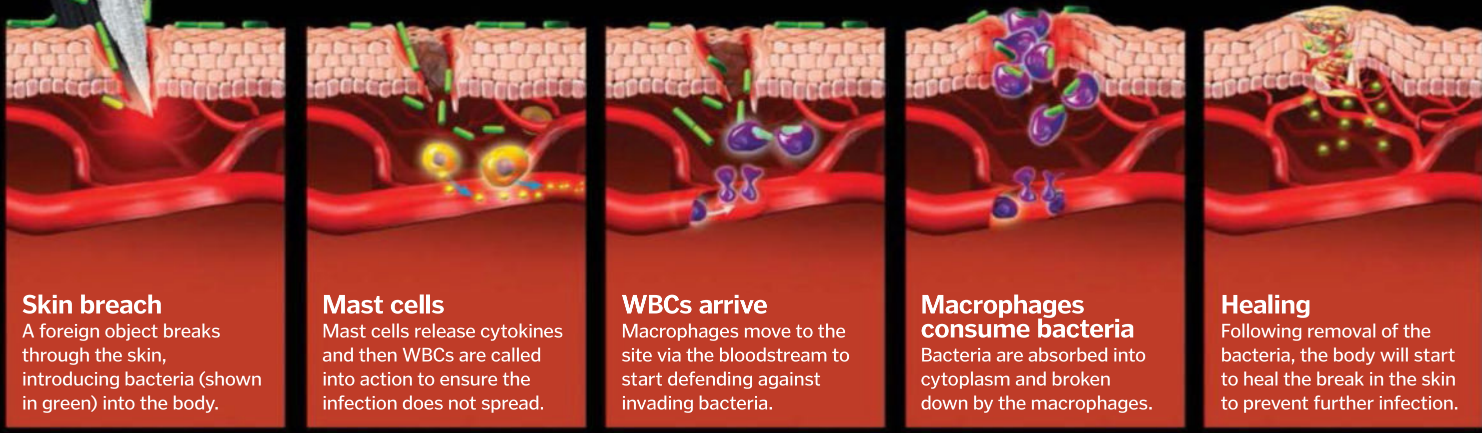


Lymphocyte
These release antibodies as well as attack virus and tumour cells through three differing types of cell. As a group, they are some of the longest lived of the white blood cells with the memory cells surviving for years to allow the body to defend itself if repeat attacks occur.

Eosinophil
Eosinophils are the white blood cells that primarily deal with parasitic infections. They also have a role in allergic reactions. They make up a fairly small percentage of the total white blood cells in our body – about 2.3 per cent.

White blood cells at work

The body has various outer defences against infection, including the external barrier of the skin, but what happens when this is breached?



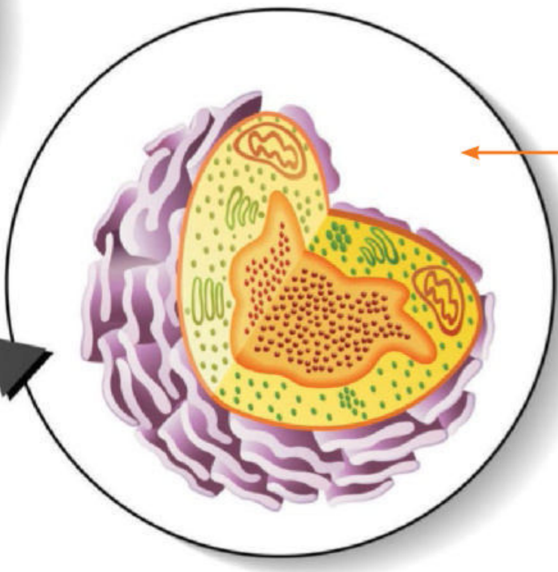
Skin breach
A foreign object breaks through the skin, introducing bacteria (shown in green) into the body.

Mast cells
Mast cells release cytokines and then WBCs are called into action to ensure the infection does not spread.

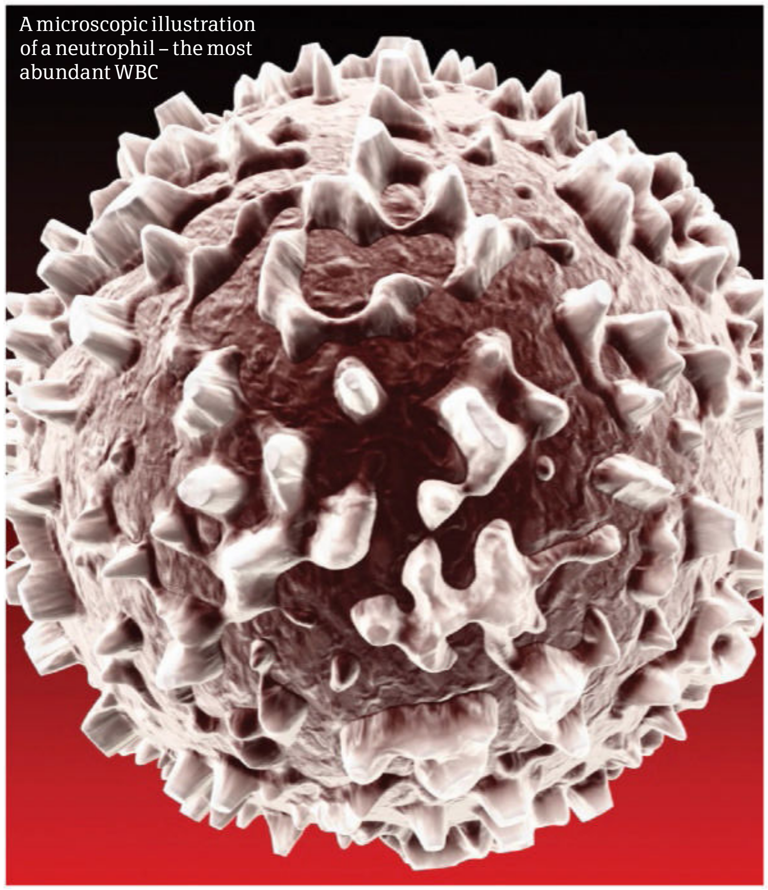
WBCs arrive
Macrophages move to the site via the bloodstream to start defending against invading bacteria.

Macrophages consume bacteria
Bacteria are absorbed into cytoplasm and broken down by the macrophages.

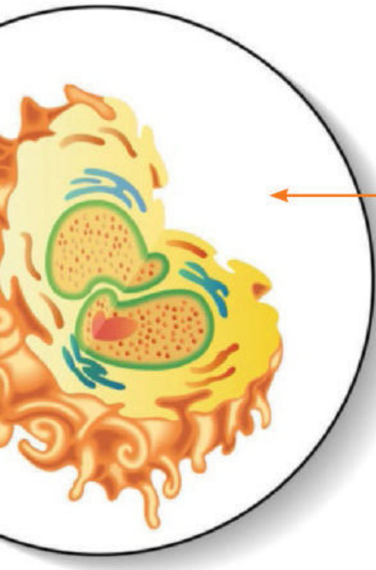
Healing
Following removal of the bacteria, the body will start to heal the break in the skin to prevent further infection.



Basophil
Basophils are involved in allergic response via releasing histamine and heparin into the bloodstream. Their functions are not fully known and they only account for 0.4 per cent of the body's white blood cells. Their granules appear blue when viewed under a microscope.



A microscopic illustration of a neutrophil – the most abundant WBC



Neutrophil
Neutrophils are the most common of the leukocytes. They have a short life span so need to be constantly produced by the bone marrow. Their granules appear pink and the cell has multi-lobed nuclei which make them easily differentiated from other types of white blood cell.

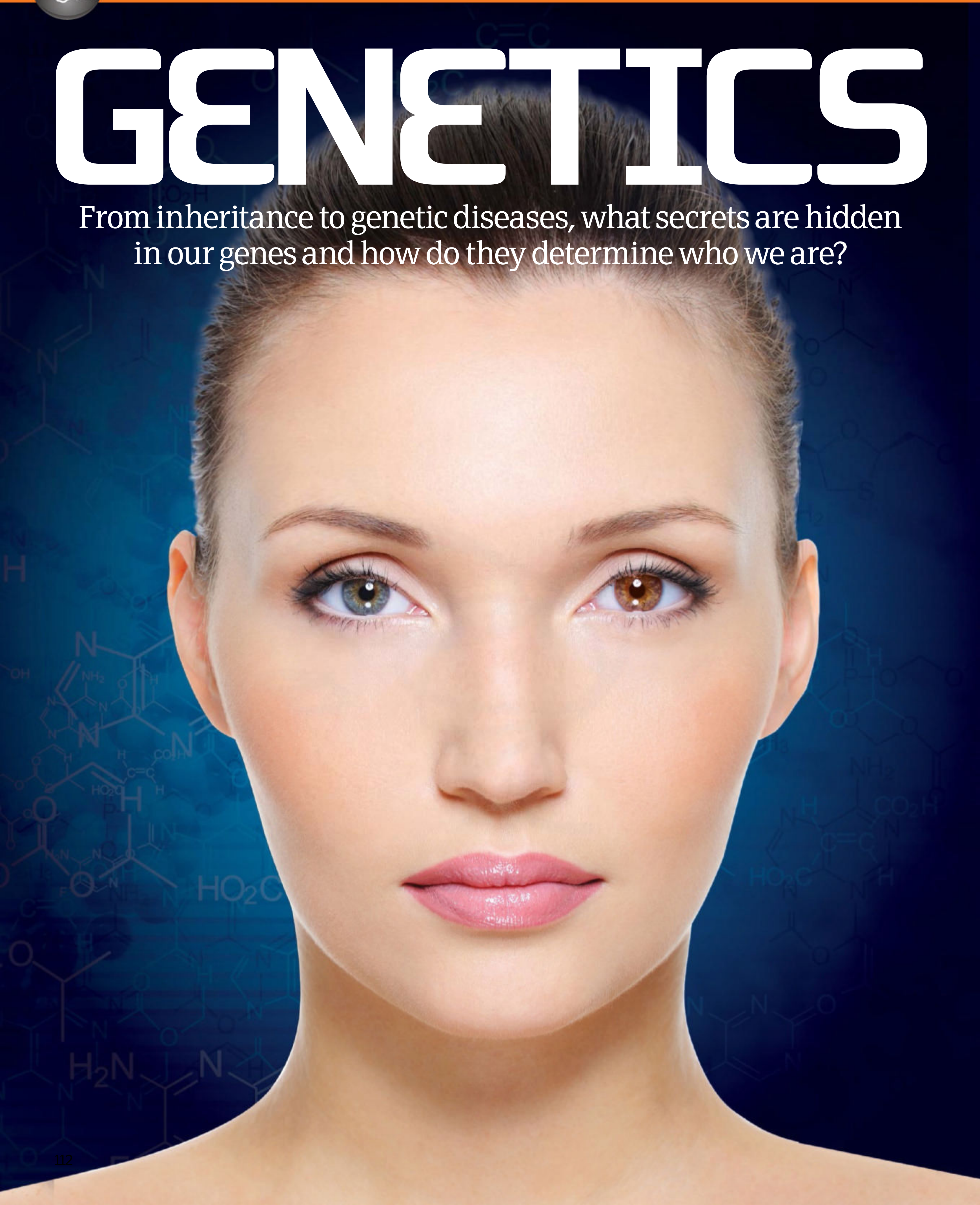
A faulty immune system

If the immune system stops working properly, we are at risk of becoming ill. However, another problem is if the immune system actually goes into overdrive and starts attacking the individual's cells, mistaking them for pathogens. There are a large number of autoimmune ailments seen across the world, such as Crohn's disease, psoriasis, lupus and some cases of arthritis, as well as a large number of diseases that are suspected to have autoimmune roots.

We can often treat these conditions with immunosuppressants, which deactivate elements of the immune system to stop the body attacking itself. However, there are drawbacks with this treatment as, if the person exposes themselves to another pathogen, they would not have the normal white blood cell response. Consequently, the individual is less likely to be able to fight normally low-risk infections and, depending on the pathogen, they can even be fatal.

GENETICS

From inheritance to genetic diseases, what secrets are hidden in our genes and how do they determine who we are?



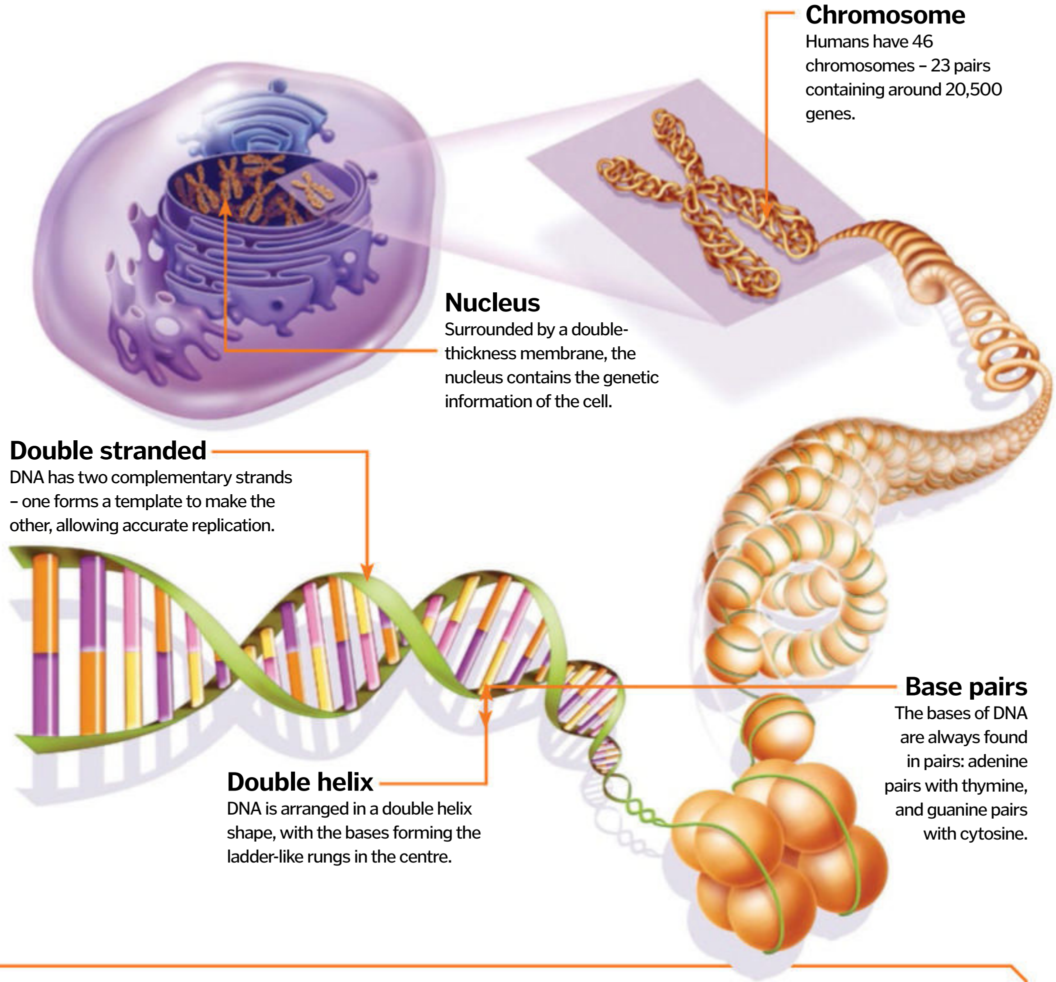
Genes define who we are. They are the basic unit of heredity, each containing a coded set of instructions to make a protein. Humans have an estimated 20,500 genes, varying in length from a few hundred to more than 2 million base pairs. They affect all aspects of our physiology, providing the code that determines our physical appearance, the biochemical reactions that occur inside our cells and even, many argue, our personalities.

Every individual has two copies of every gene – one inherited from each parent. Within the population there are several alleles of each gene – that is, different forms of the same code, with a number of minor alterations in the sequence. These alleles perform the same underlying function, but it is the subtle differences that make each of us unique.

Inside each of our cells (except red blood cells) is a nucleus, the core which contains our genetic information: deoxyribonucleic acid (DNA). DNA is a four-letter code made up of bases: adenine (A), guanine (G), cytosine (C) and thymine (T). As molecular biologist Francis Crick once put it, "DNA makes RNA, RNA makes protein and proteins make us." Our genes are stored in groups of several thousand on 23 pairs of chromosomes in the nucleus, so when a cell needs to use one particular gene, it makes a temporary copy of the sequence in the form of ribonucleic acid (RNA). This copy contains all of the information required to

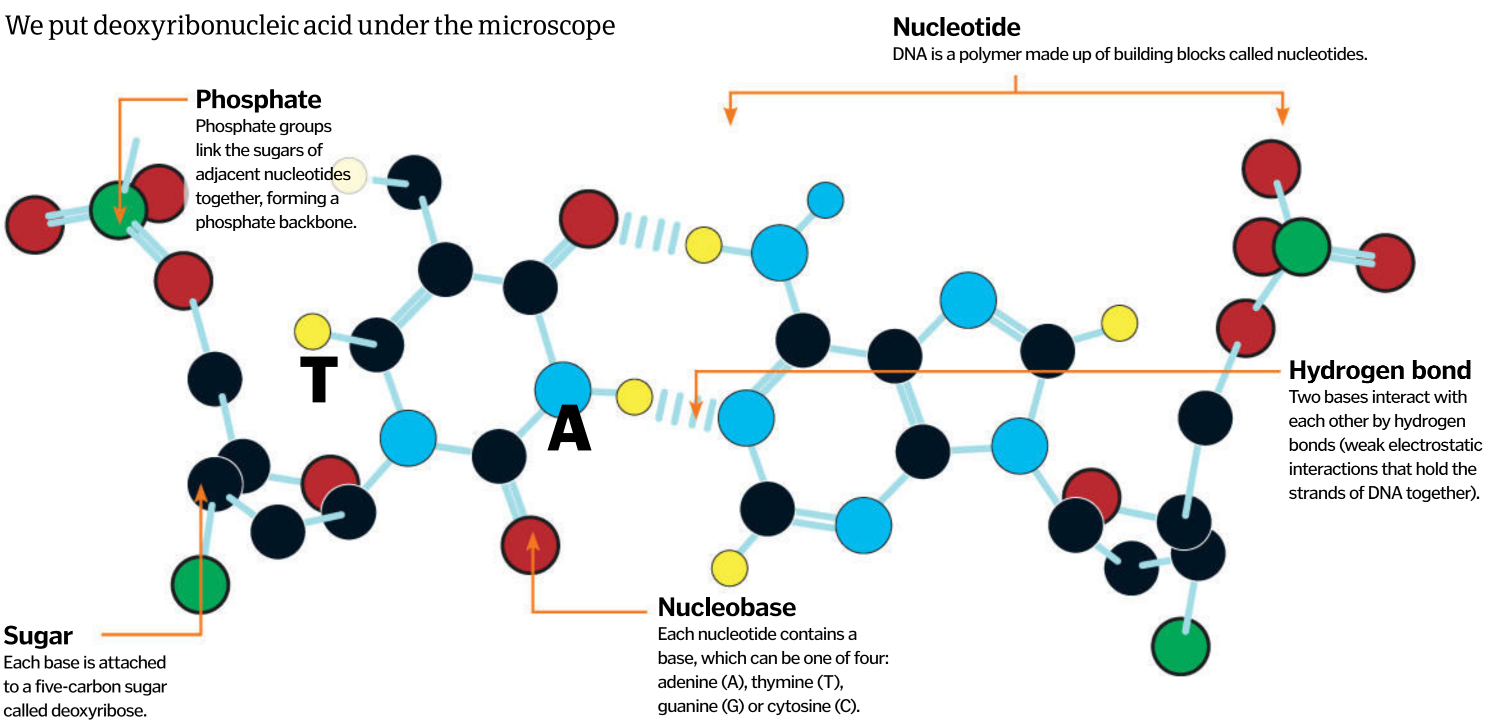
How is our genetic code stored?

Genetic information is coded into DNA using just four nucleobases: A, C, G and T



DNA's chemical structure

We put deoxyribonucleic acid under the microscope



make a protein – the building blocks of the human body.

The Human Genome Project aimed to map the entire human genome; this map is effectively a blueprint for making a human. Using the information hidden within our genetic code, scientists have been able to identify genes that contribute to various diseases. By logging common genetic variation in the human population, researchers have been able to identify over 1,800 disease-associated genes, affecting illnesses ranging from breast cancer to Alzheimer's. The underlying genetic influences that affect complex diseases like heart disease are not yet fully understood, but having the genome available to study is making the task of identifying genetic risk factors much easier.

Interestingly, the Human Genome Project discovered we have far fewer genes than first predicted; in fact, only two per cent of our genome codes for proteins. The remainder of the DNA is known as 'non-coding' and serves other functions. In many human genes are non-coding regions called introns, and between genes there is intergenic DNA. One proposed function is that these sequences act as a buffer to protect the important genetic information from mutation. Other non-coding DNA acts as switches, helping the cell to turn genes on and off at the right times.

Genetic mutations are the source of variation in all organisms. Most genetic mutation occurs as the DNA is being copied, when cells prepare to divide. The molecular machinery responsible for duplicating DNA is prone to errors, and often makes mistakes, resulting in changes to the DNA sequence. These can be as simple as accidentally substituting one base for another (eg A for G), or can be much larger errors, like adding or deleting bases. Cells have repair machinery to correct errors as they occur, and even to kill the cell if it makes a big mistake, but despite this some errors still slip through.

Throughout your life you will acquire many cell mutations. Many of these are harmless, either occurring in non-coding regions of DNA,

The Human Genome Project

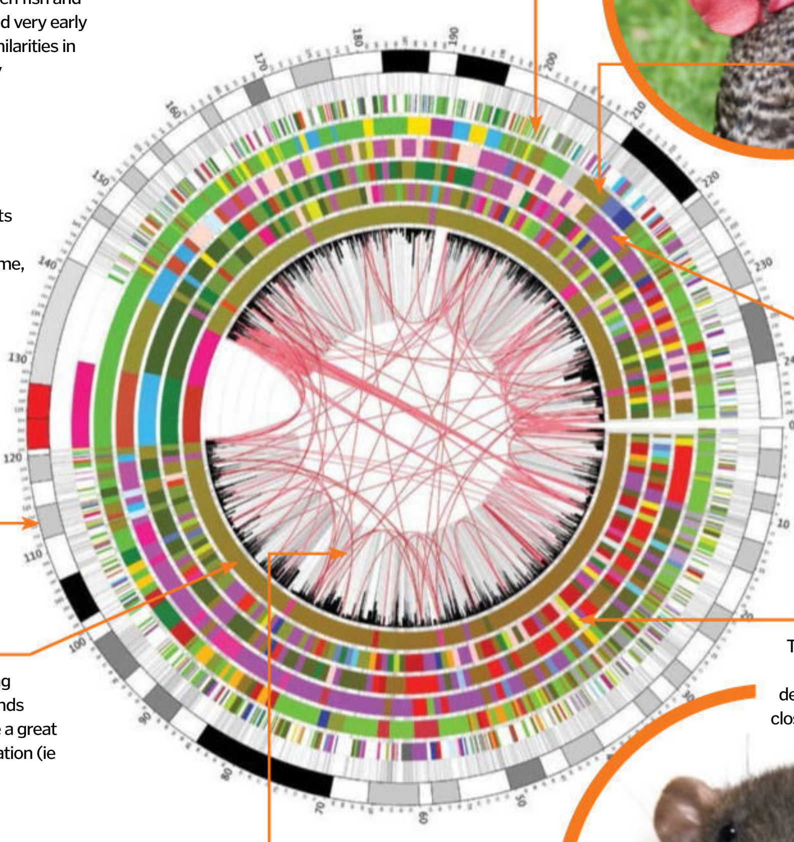
The Human Genome Project, an initiative to map the sequence of the entire human genetic code, began in 1990 and was completed in 2003. The 3.3-billion base pair sequence was broken into sections of around 150,000 base pairs in length and the sequence for each identified. These were then joined and used to map the information on to chromosomes to determine which genes were found on each – and in what order. The genome map (right) shows a human chromosome compared with other animals; the colours are a 'heat map' demonstrating areas where genetic information has been conserved through evolution (the more fragmented the pattern, the more differences there are in the genetic code).

Mapping the human genome

How does our genetic makeup compare to that of other creatures?

Zebrafish
Divergence between fish and mammals occurred very early in evolution, so similarities in our genes are very fragmented.

Human
This ring represents the genes on a human chromosome, with the numbers providing a representation of scale.



Chicken
Despite the fact that we are not closely related to birds, the chicken still has regions of DNA that are quite similar to ours.

Dog
Some regions of the canine genome are very different to ours, but the pink bands show an area that has been conserved.

Rat
The mouse and rat genomes have similar patterns, demonstrating these rodents' close evolutionary relationship.

Chimpanzee
One of our closest living relatives – the solid bands demonstrate we share a great deal of genetic information (ie 98 per cent).

Mouse
There is less in common between human and mouse (90 per cent), but we are sufficiently similar that mice make a good scientific model for studying human disease.

or changing the gene so nominally that the protein is virtually unaffected. However, some mutations do lead to disease.

If mutations are introduced into the sperm and egg cells they can be passed on to the next generation. However, not all mutations are bad, and this process of randomly introduced changes in the DNA sequence provides the biological underpinning that supports Darwin's theory of evolution. This is most easily observed in animals. Take, for example, the peppered moth. Before the Industrial Revolution the majority of these moths had white wings, enabling them to hide against light-coloured trees and lichens. A minority had a mutant gene, which gave them black wings; this made them an easy target for predators. When factories began to cover the trees in soot, the light-coloured moths struggled to hide themselves against the darker environment, so black moths flourished. They survived much longer, enabling them to pass on their mutation to their offspring and altering the gene pool.

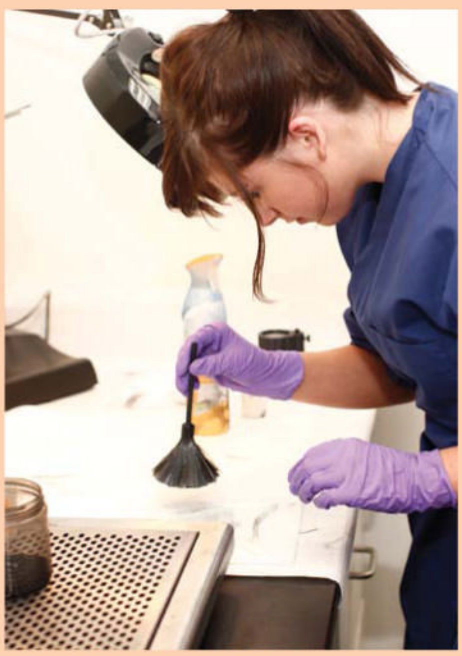
> "Before the Industrial Revolution the majority had white wings"

It is easy to see how a genetic change like the one that occurred in the peppered moth could give an advantage to a species, but what about genetic diseases? Even these can work to our advantage. A good example is sickle cell anaemia – a genetic disorder that's quite common in the African population.

A single nucleotide mutation causes haemoglobin, the protein involved in binding oxygen in red blood cells, to misfold. Instead of forming its proper shape, the haemoglobin clumps together, causing red blood cells to deform. They then have trouble fitting through narrow capillaries and often become damaged or destroyed. However, this genetic mutation persists in the population because it has a protective effect against malaria. The malaria parasite spends part of its life cycle inside red blood cells and, when sickle cells rupture, it prevents the parasite from reproducing. Individuals with one copy of the sickle cell gene and one copy of the healthy haemoglobin gene have few symptoms of sickle cell anaemia,

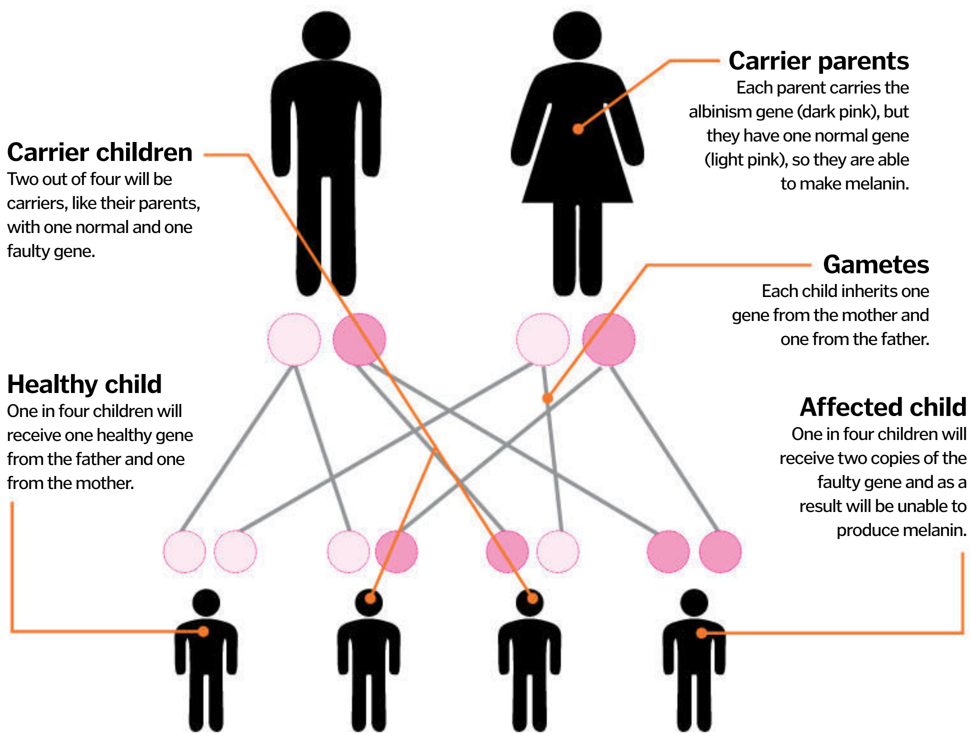
Using genetics to convict criminals

Forensic scientists can use traces of DNA to identify individuals involved in criminal activity. Only about 0.1 per cent of the genome differs between individuals, so rather than sequencing the entire genome, scientists take 13 DNA regions that are known to vary between different people in order to create a 'DNA fingerprint'. In each of these regions there are two to 13 nucleotides in a repeating pattern hundreds of bases long – the length varies between individuals. Small pieces of DNA – referred to as probes – are used to identify these repeats and the length of each is determined by a technique called polymerase chain reaction (PCR). The odds that two people will have exactly the same 13-region profile is thought to be one in a billion or even less, so if all 13 regions are found to be a match then scientists can be fairly confident that they can tie a person to a crime scene.



Why do we look like our parents?

It's a common misconception that we inherit entire features from our parents – eg "You have your father's eyes." Actually inheritance is much more complicated – several genes work together to create traits in physical appearance; even eye colour isn't just down to one gene that codes for 'blue', 'brown' or 'green', etc. The combinations of genes from both of our parents create a mixture of their traits. However, there are some examples of single genes that do dictate an obvious physical characteristic all on their own. These are known as Mendelian traits, after the scientist Gregor Mendel who studied genetic inheritance in peas in the 1800s. One such trait is albinism – the absence of pigment in the skin, hair and eyes due to a defect in the protein that makes melanin.



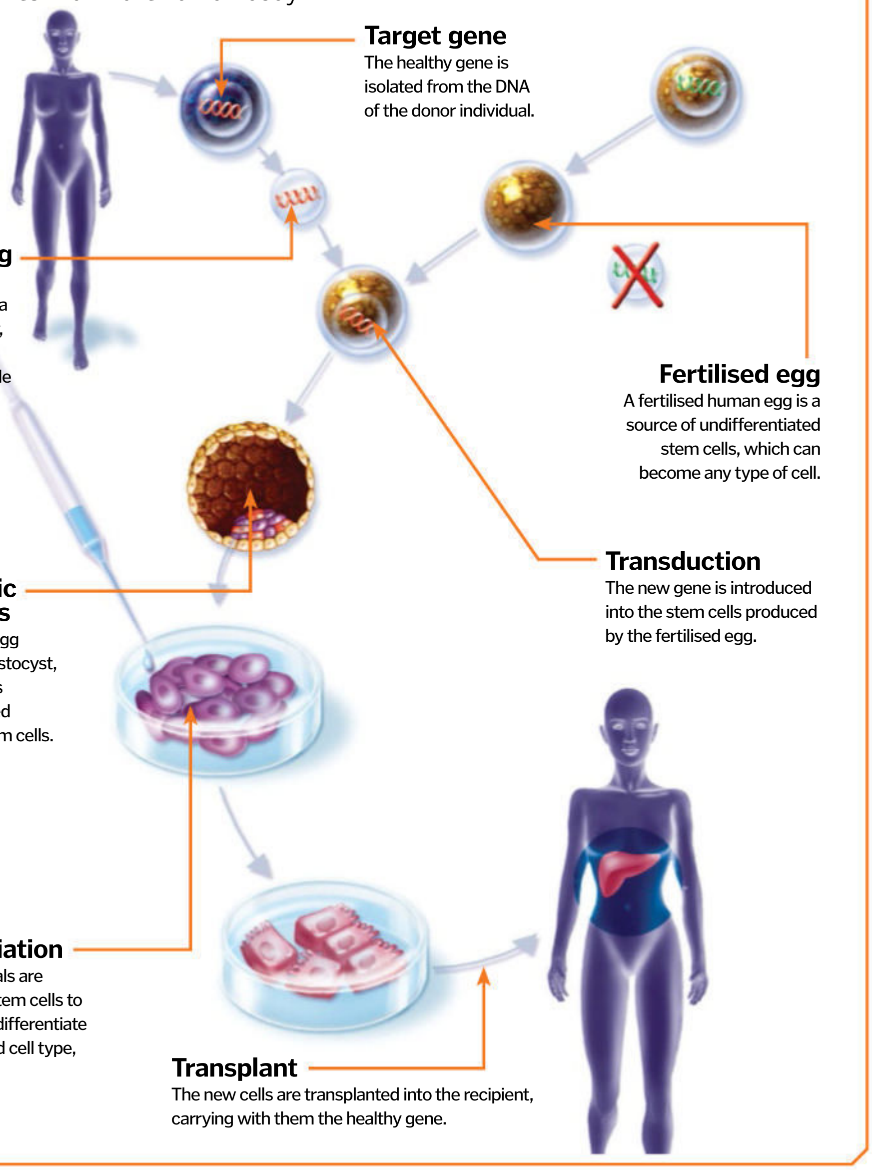
but are protected from malaria too, allowing them to pass the gene on to their children.

Genetics is a complex and rapidly evolving field and more information about the function of DNA is being discovered all the time. It is now known that environmental influences can alter the way that DNA is packaged in the cell, restricting access to some genes and altering protein expression patterns. Known as epigenetics, these modifications do not actually alter the underlying DNA sequence, but regulate how it is accessed and used by the cell. Epigenetic changes can be passed on from one cell to its offspring, and thus provide an additional mechanism by which genetic information can be modified across generations of humans.

"Environmental influences can alter the way that DNA is packaged"

Repairing faulty genes

We reveal how donated cells can be used to mend any damaged genes within the human body



Target gene
The healthy gene is isolated from the DNA of the donor individual.

Packaging
The gene is packaged into a delivery vector, like a virus, to help it get inside the target cell.

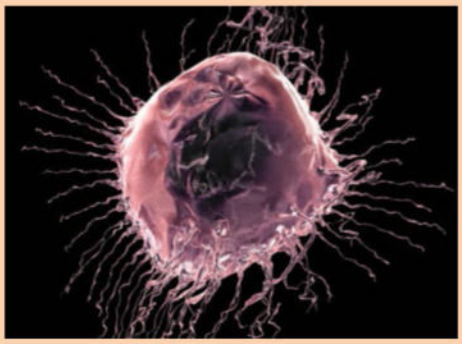
Fertilised egg
A fertilised human egg is a source of undifferentiated stem cells, which can become any type of cell.

Embryonic stem cells
The fertilised egg becomes a blastocyst, which contains undifferentiated embryonic stem cells.

Transduction
The new gene is introduced into the stem cells produced by the fertilised egg.

Differentiation
Chemical signals are added to the stem cells to force them to differentiate into the desired cell type, eg liver cells.

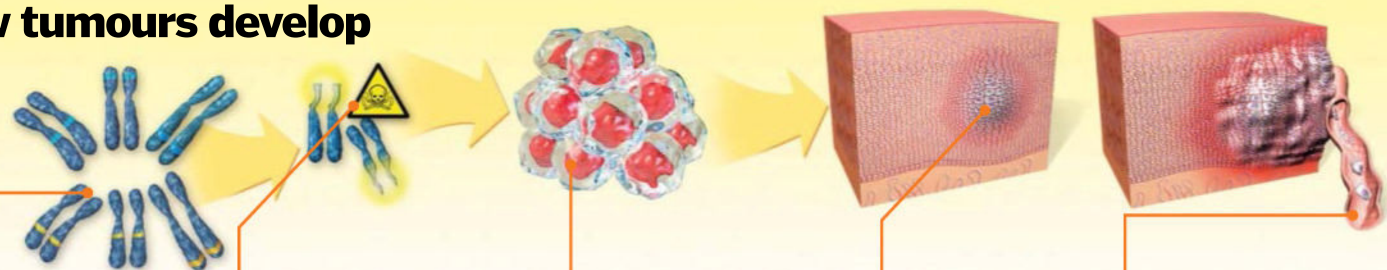
Transplant
The new cells are transplanted into the recipient, carrying with them the healthy gene.



When our genes go wrong…

Cancer is not just the result of one or two genetic mutations – in fact, it takes a whole series of mistakes for a tumour to form. Cells contain oncogenes and tumour suppressor genes, whose healthy function is to tell the cell when it should and should not divide. If these become damaged, the cell cannot switch off its cell division programme and it will keep making copies of itself indefinitely. Each time a cell divides there is a risk that it will make a mistake when copying its DNA, and gradually the cell makes more and more errors, accumulating mutations that allow the tumour to progress into malignant cancer.

How tumours develop



Tumour-associated genes
Genes normally involved in regulating cell behaviour can go on to cause cancer if they become mutated.

Mutagens
Environmental factors, or mutagens – such as radiation and chemicals – can cause damage to the DNA, leading to mutations in key genes.

Localised
Cancer usually starts with just one or a few mutated cells; these begin to divide uncontrollably in their local area creating a tumour.

Invasion
As the tumour grows in size it starts to invade the surrounding area, taking over neighbouring tissues.

Metastasis
Further mutations allow cells of the tumour to break free and enter the bloodstream. From here they can be distributed throughout the body.

What is anxiety?

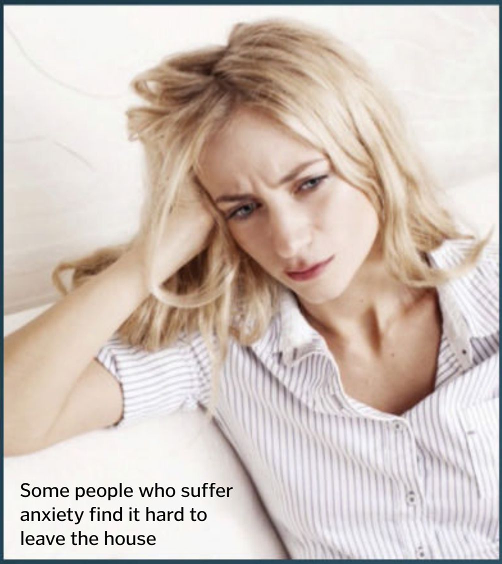
How our brains trigger a fight or flight response

Anxiety affects a huge number of people and can be so severe that it stops many sufferers from leaving their homes or doing their jobs. In the US, over 40 million people aged 18 or over endure an anxiety related disorder, while in the UK one in 20 people are affected. Some researchers believe that modern day technology has influenced the rise of anxiety related conditions; we are constantly on high alert with texts, emails, social media and news updates.

Anxiety is a natural human response that serves a purpose. From a biological point of view, it functions to create a heightened sense of awareness, preparing us for potential threats. In a way, it's nature's panic button.

When we become anxious our fight or flight response is triggered, flooding our bodies with epinephrine (adrenaline), norepinephrine (noradrenaline) and cortisol, which help increase your reflexes and reaction speed. Your body prepares itself to deal with danger by increasing the heart rate, pumping more blood to the muscles and by getting the lungs to hyperventilate.

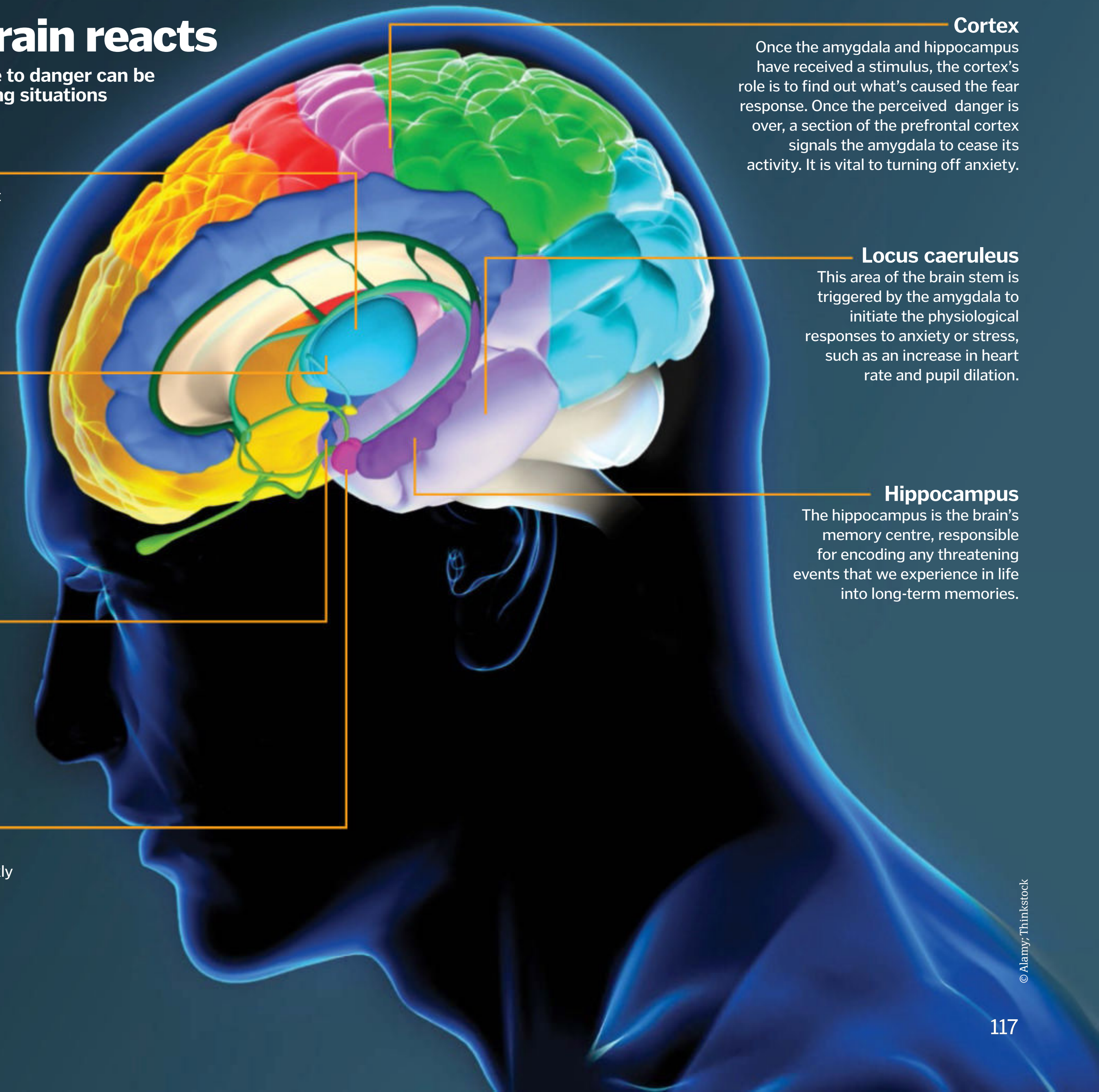
At the same time, the brain stops thinking about pleasurable things, making sure that all of its focus is on identifying potential threats. In extreme cases, the body will respond to anxiety by emptying the digestive tract by any means necessary, as this ensures that no energy is wasted on digestion.



Some people who suffer anxiety find it hard to leave the house

How your brain reacts

The body's primal response to danger can be triggered by non-threatening situations



Thalamus
Visual and auditory stimuli are first processed by the thalamus which filters the incoming information and sends it to the areas where it can be interpreted.

Two paths
A startling signal such as a sudden loud noise will be sent from the thalamus via two paths: one travels directly to the amygdala - where it can quickly initiate the fear response - and the other passes through the cortex to be processed more thoroughly.

Stria terminalis
The bed nucleus of the stria terminalis (BNST) is responsible for maintaining fear once this emotion has been stimulated by the amygdala, leading to longer-term feelings of anxiety.

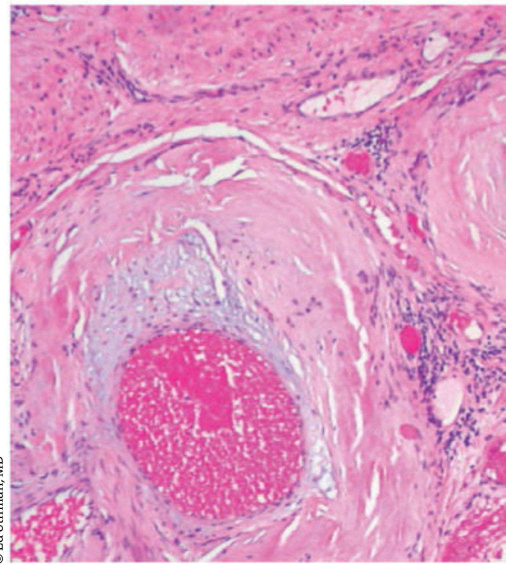
Amygdala
This is where the fear response is triggered. The amygdala can quickly put your body on high alert, and research suggests that if this area of the brain is overactive, it may cause an anxiety disorder.

Cortex
Once the amygdala and hippocampus have received a stimulus, the cortex's role is to find out what's caused the fear response. Once the perceived danger is over, a section of the prefrontal cortex signals the amygdala to cease its activity. It is vital to turning off anxiety.

Locus caeruleus
This area of the brain stem is triggered by the amygdala to initiate the physiological responses to anxiety or stress, such as an increase in heart rate and pupil dilation.

Hippocampus
The hippocampus is the brain's memory centre, responsible for encoding any threatening events that we experience in life into long-term memories.

Inside the circulatory system



Most of the amyloid consisted of acellular pink globules that effaced and expanded the node, but this image shows the characteristic involvement of blood vessel walls

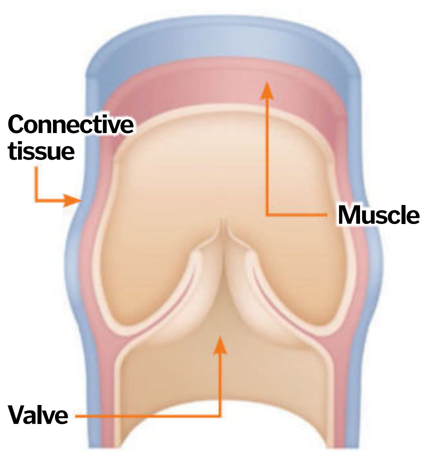
Arteries and veins form the plumbing system that carries blood around the body. Find out more about the circular journey it takes...

The network of blood vessels in the human body must cope with different volumes of blood travelling at different pressures. These blood vessels come in a multitude of different sizes and shapes, from the large, elastic aorta down to very tiny, one-cell-thick capillaries.

Blood is the ultimate multitasker. It carries oxygen for various tissues to use, nutrients to provide energy, removes waste products and even helps you warm up or cool down. It also carries vital clotting factors which stop us bleeding. Blood comes in just two varieties; oxygen-rich (oxygenated) blood is what the body uses for energy, and is bright red. After it has been used, this oxygen-depleted (deoxygenated) blood is returned for recycling and is dark red (not blue, as is often thought).

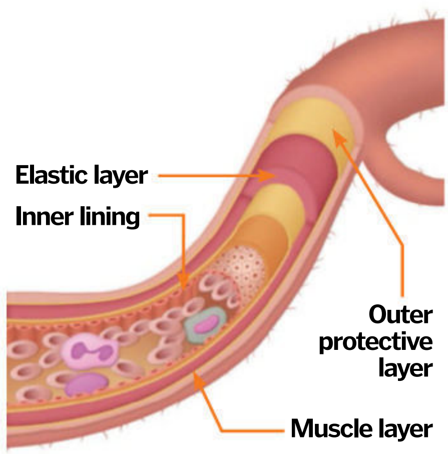
Blood is carried in vessels, of which there are two main different types – arteries and veins. Arteries carry blood away from the heart and deal with high pressures, and so have strong elastic walls. Veins carry blood back towards the heart and deal with lower pressures, so have thinner walls. Tiny capillaries connect arteries and veins together, like small back-roads connecting motorways to dual carriageways.

Arteries and veins are constructed differently to cope with the varying pressures, but work in tandem to ensure that the blood reaches its final destination. However, sometimes things go wrong, lead to certain medical problems: varicose veins from failing valves; deep vein thrombosis from blood clots blocking the deep venous system; heart attacks from blocked arteries; and lastly life-threatening aneurysms from weak artery walls.



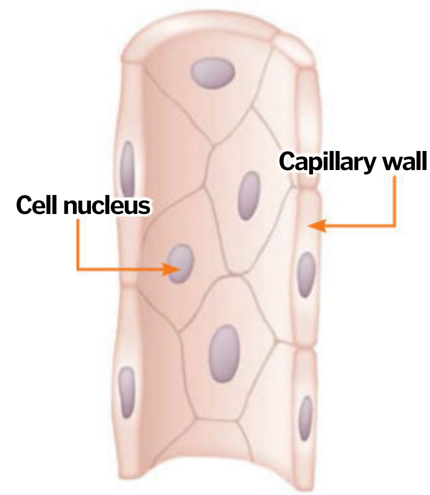
How do veins work?

Veins carry low pressure blood. They contain numerous one-way valves which stop backwards flow of blood, which can occur when pressure falls in-between heartbeats. Blood flows through these valves towards the heart but cannot pass back through them in the other direction. Valves can fail over time, especially in the legs. This leads to saggy, unsightly veins, known as varicose veins.



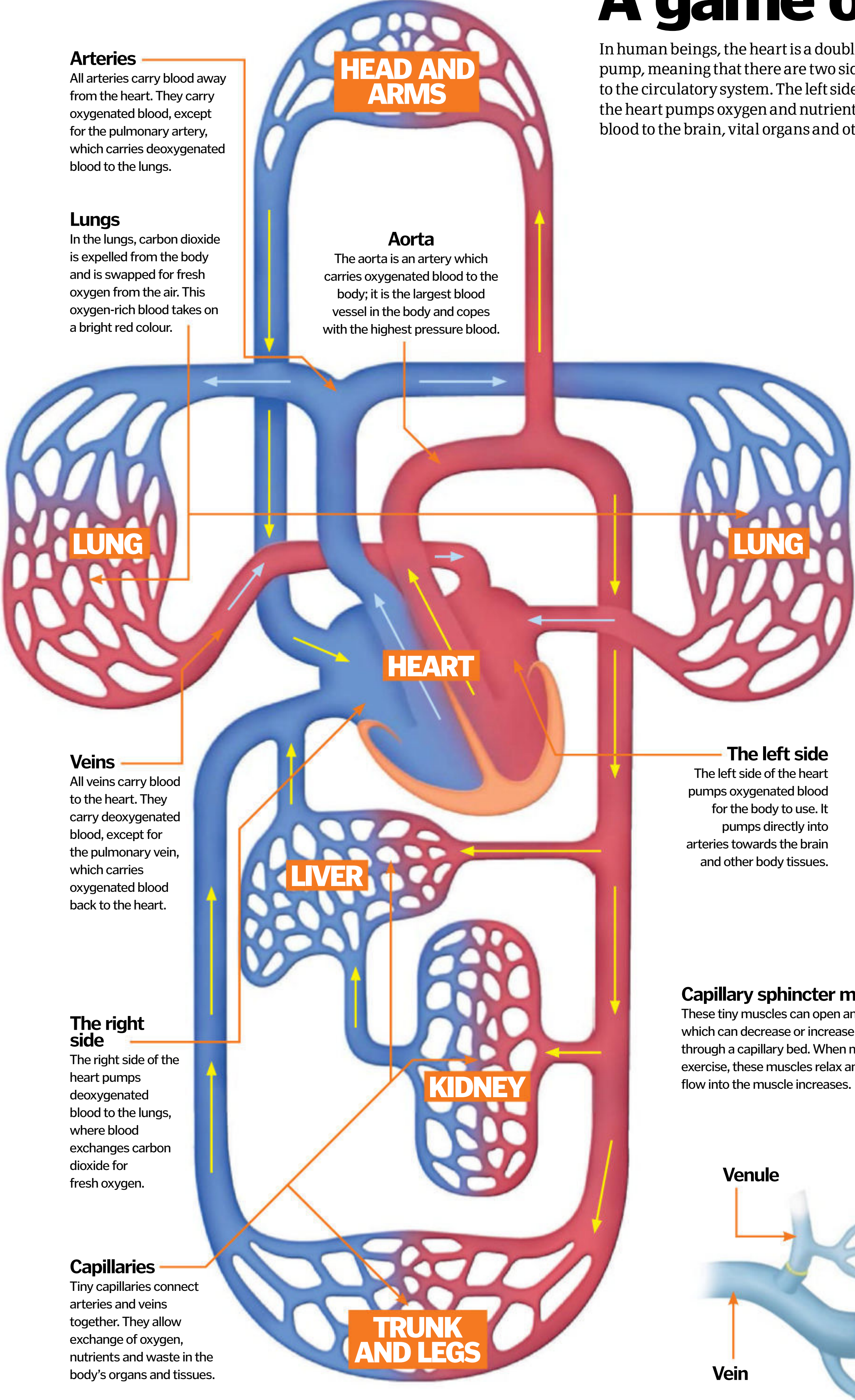
Arteries – under pressure!

Arteries cope with all of the pressure generated by the heart and deliver oxygen-rich blood to where it needs to be 24 hours a day. The walls of arteries contain elastic muscles, allowing them to stretch and contract to cope with the wide changes in pressure generated from the heart. Since the pressure is high, valves are unnecessary, unlike the low-pressure venous system.



Connecting it all together

Capillaries are the tiny vessels which connect small arteries and veins together. Their walls are only one cell thick, so this is the perfect place to trade substances with surrounding tissues. Red blood cells within these capillaries trade water, oxygen, carbon dioxide, nutrients, waste and even heat. Because these vessels are only one cell wide, the cells have to line up to pass through.



A game of two halves

In human beings, the heart is a double pump, meaning that there are two sides to the circulatory system. The left side of the heart pumps oxygen and nutrient-rich blood to the brain, vital organs and other body tissues (the systemic circulation). The right side of the heart pumps deoxygenated blood towards the lungs, so it can pick up new oxygen molecules to be used again (the pulmonary circulation).

"Plasma carries all of the different types of cells"

What's in blood?

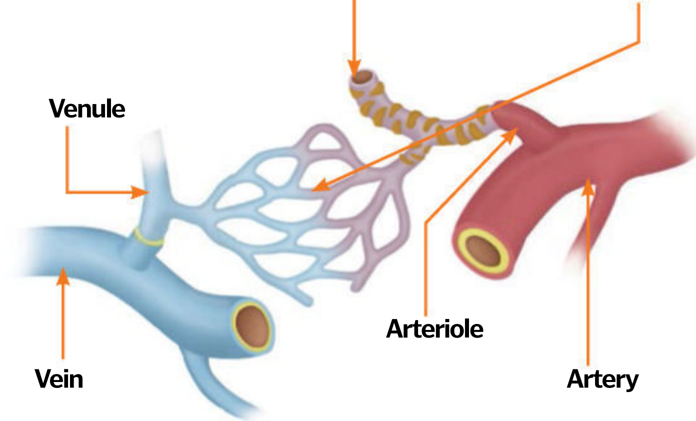
It's only the iron in red blood cells which make blood red – take these cells away and what you're left with is a watery yellowish solution called plasma. Plasma carries all of the different types of cells and also contains sugars, fats, proteins and salts. The main cell types are red blood cells (formed from iron and haemoglobin, which carries oxygen around the body), white blood cells (which fight infection from bacteria, viruses and fungi) and platelets (tiny cell fragments which stop bleeding by forming clots at the sites of any damage).

Blood vessels

Different shapes and sizes

Capillary sphincter muscles
These tiny muscles can open and close, which can decrease or increase blood flow through a capillary bed. When muscles exercise, these muscles relax and blood flow into the muscle increases.

Capillary bed
This is the capillary network that connects the two systems. Here, exchange of various substances occurs with surrounding tissues, through the one-cell thick walls.



How your blood works

The science behind the miraculous fluid that feeds, heals and fights for your life

White blood cells

White blood cells, or leukocytes, are the immune system's best weapon, searching out and destroying bacteria and producing antibodies against viruses. There are five different types of white blood cells, all with distinct functions.

Platelet

When activated, these sticky cell fragments are essential to the clotting process. Platelets adhere to a wound opening to stem the flow of blood, then they team with a protein called fibrinogen to weave tiny threads that trap blood cells.

Red blood cell

Known as erythrocytes, red blood cells are the body's delivery service, shuttling oxygen from the lungs to living cells throughout the body and returning carbon dioxide as waste.

Blood vessel wall

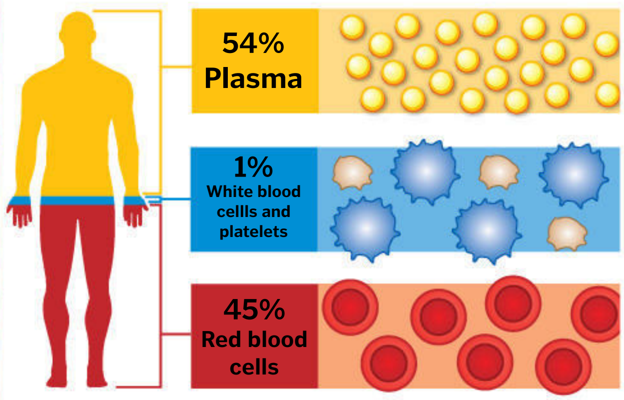
Arteries and veins are composed of three tissue layers, a combination of elastic tissue, connective tissue and smooth muscle fibres that contract under signals from the sympathetic nervous system.

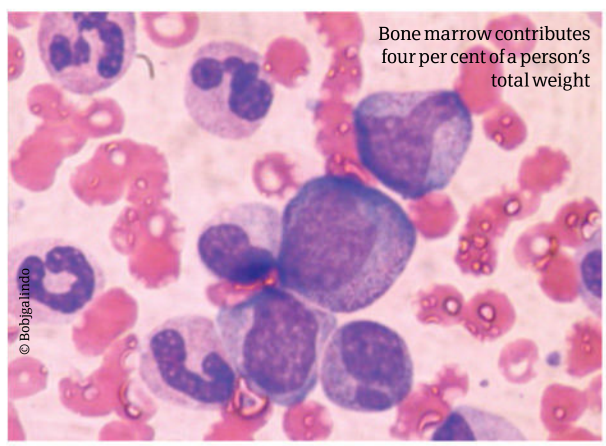
Granulocyte

The most numerous type of white blood cell, granulocytes patrol the bloodstream destroying invading bacteria by engulfing and digesting them, often dying in the process.

Components of blood

Blood is a mix of solids and liquids, a blend of highly specialised cells and particles suspended in a protein-rich fluid called plasma. Red blood cells dominate the mix, carrying oxygen to living tissue and returning carbon dioxide to the lungs. For every 600 red blood cells, there is a single white blood cell, of which there are five different kinds. Cell fragments called platelets use their irregular surface to cling to vessel walls and initiate the clotting process.





Bone marrow contributes four per cent of a person's total weight

> *"Red blood cells are so numerous because they perform the most essential function of blood"*

Blood is the river of life. It feeds oxygen and essential nutrients to living cells and carries away waste. It transports the foot soldiers of the immune system, white blood cells, which seek out and destroy invading bacteria and parasites. And it speeds platelets to the site of injury or tissue damage, triggering the body's miraculous process of self-repair.

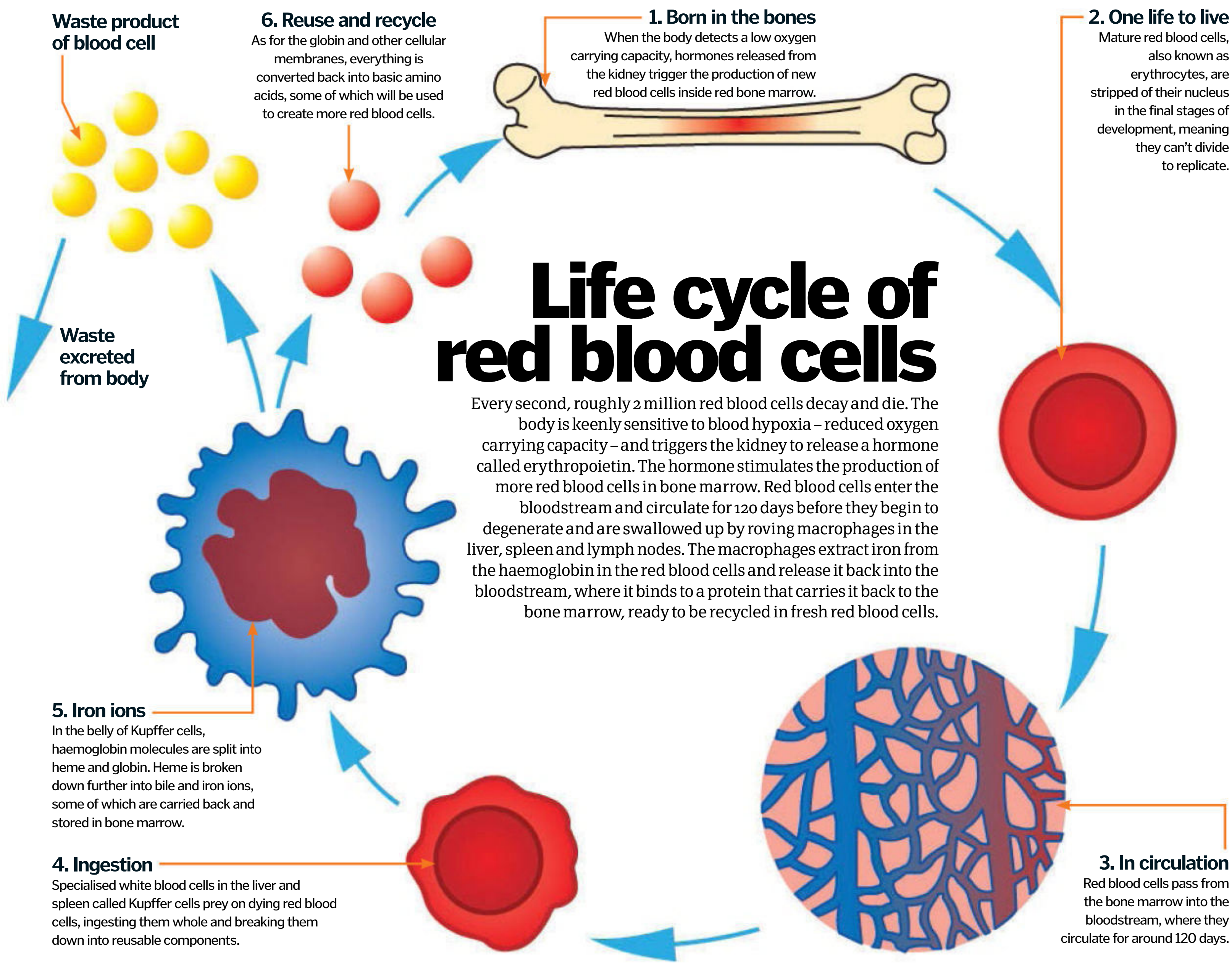
Blood looks like a thick, homogenous fluid, but it's more like a watery current of plasma – a straw-coloured, protein-rich fluid – carrying billions of microscopic solids consisting of red blood cells, white blood cells and cell fragments called platelets. The distribution is far from equal. Over half of blood is plasma, 45 per cent is red blood cells and a tiny fragment, less than one per cent, is composed of white blood cells and platelets.

Red blood cells are so numerous because they perform the most essential function of blood, which is to deliver oxygen to every cell in the body and carry away carbon dioxide. As an adult, all of your red blood cells are produced in red bone marrow, the spongy tissue in the bulbous ends of long bones and at the centre of flat bones like hips and ribs. In the marrow, red blood cells start out as undifferentiated stem cells called hemocytoblasts. If the body detects a minuscule drop in oxygen carrying capacity, a hormone is released from the kidneys that triggers the stem cells to become red blood cells. Because red blood cells only live 120 days, the supply must be continuously replenished; roughly 2 million red blood cells are born every second.

A mature red blood cell has no nucleus. The nucleus is spit out during the final stages of the cell's two-day development before taking on the shape of a concave, doughnut-like disc. Like all cells, red blood cells are mostly water, but 97 per cent of their solid matter is haemoglobin, a complex protein that carries four atoms of iron. Those iron atoms have the ability to form loose, reversible

Life cycle of red blood cells

Every second, roughly 2 million red blood cells decay and die. The body is keenly sensitive to blood hypoxia – reduced oxygen carrying capacity – and triggers the kidney to release a hormone called erythropoietin. The hormone stimulates the production of more red blood cells in bone marrow. Red blood cells enter the bloodstream and circulate for 120 days before they begin to degenerate and are swallowed up by roving macrophages in the liver, spleen and lymph nodes. The macrophages extract iron from the haemoglobin in the red blood cells and release it back into the bloodstream, where it binds to a protein that carries it back to the bone marrow, ready to be recycled in fresh red blood cells.



bonds with both oxygen and carbon dioxide – think of them as weak magnets – making red blood cells such an effective transport system for respiratory gasses. Haemoglobin, which turns bright red when oxygenated, is what gives blood its characteristic colour.

To provide oxygen to every living cell, red blood cells must be pumped through the body's circulatory system. The right side of the heart pumps CO_2-heavy blood into the lungs, where it releases its waste gasses and picks up oxygen. The left side of the heart then pumps the freshly oxygenated blood out into the body through a system of arteries and capillaries, some as narrow as a single cell. As the red blood cells release their oxygen, they pick up carbon dioxide molecules, then course through the veins back toward the heart, where they are pumped back into the lungs to 'exhale' the excess CO_2 and collect some more precious O_2.

White blood cells are greatly outnumbered by red blood cells, but they are critical to the function of the immune system. Most white blood cells are also produced in red bone marrow, but white blood cells – unlike red blood cells – come in five different varieties, each with its own specialised immune function. The first three varieties, collectively called granulocytes, engulf and digest bacteria and parasites, and play a role in allergic reactions. Lymphocytes, another type of white blood cell, produce anti-bodies that build up our immunity to repeat intruders. And monocytes, the largest of the white blood cells, enter organ tissue and become macrophages, microbes that ingest bad bacteria and help break down dead red blood cells into reusable parts.

Platelets aren't cells at all, but fragments of much larger stem cells found in bone marrow. In their resting state, they look like smooth oval plates, but when activated to form a clot they take on an irregular form with many protruding arms called pseudopods. This shape helps them stick to blood vessel walls and to each other, forming a physical barrier around wound sites. With the help of proteins and clotting factors found in plasma, platelets weave a mesh of fibrin that stems blood loss and triggers the formation of new collagen and skin cells.

But even these three functions of blood – oxygen supplier, immune system defender and wound healer – only begin to scratch the surface of the critical role of blood in each and every bodily process. When blood circulates through the small intestine, it absorbs sugars from digested food, which are transported to the liver to be stored as energy. When blood passes through the kidneys, it is scrubbed of excess urea and salts, waste that will leave the body as urine. The proteins transport vitamins, hormones, enzymes, sugar and electrolytes.

Blood disorders

Blood is a delicate balancing act, with the body constantly regulating oxygen flow, iron content and clotting ability. Unfortunately, there are several genetic conditions and chronic illnesses that can disturb the balance, sometimes with deadly consequences.

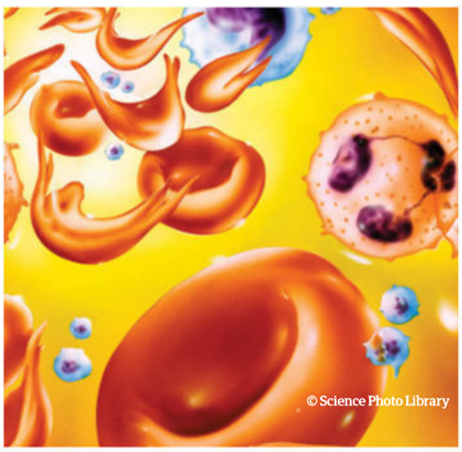
"Platelets weave a mesh of fibrin that stems blood loss"

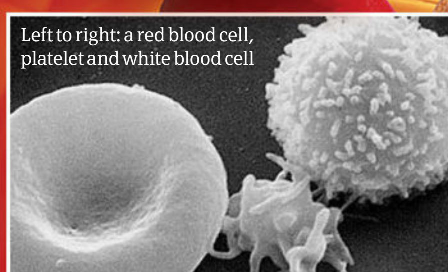
Haemophilia

This rare genetic blood disorder severely inhibits the clotting mechanism of blood, causing excessive bleeding, internal bruising and joint problems. Platelets are essential to the clotting and healing process, producing threads of fibrin with help from proteins in the bloodstream called clotting factors. People who suffer from haemophilia – almost exclusively males – are missing one of those clotting factors, making it difficult to seal off blood vessels after even minor injuries.

Sickle cell anaemia

Anaemia is the name for any blood disorder that results in a dangerously low red blood cell count. In sickle cell anaemia, which afflicts one out of every 625 children of African descent, red blood cells elongate into a sickle shape after releasing their oxygen. The sickle-shaped cells die prematurely, leading to anaemia, or sometimes lodge in blood vessels, causing terrible pain and even organ damage. Interestingly, people who carry only one gene for sickle cell anaemia are immune to malaria.



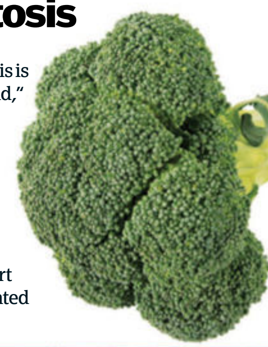


Left to right: a red blood cell, platelet and white blood cell

Thalassemia

Another rare blood disorder affecting 100,000 newborns worldwide each year, thalassemia inhibits the production of haemoglobin, leading to severe anaemia. People who are born with the most serious form of the disease, also called Cooley's anaemia, suffer from enlarged hearts, livers and spleens, and brittle bones. The most effective treatment is frequent blood transfusions, although a few lucky patients have been cured through bone marrow transplants from perfectly matching donors.

Hemochromatosis



One of the most common genetic blood disorders, hemochromatosis is the medical term for "iron overload," in which your body absorbs and stores too much iron from food. Severity varies wildly, and many people experience few symptoms, but others suffer serious liver damage or scarring (cirrhosis), irregular heartbeat, diabetes and even heart failure. Symptoms can be aggravated by taking too much vitamin C.

Deep vein thrombosis

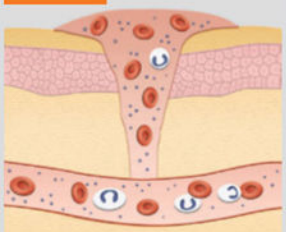
Thrombosis is the medical term for any blood clot that is large enough to block a blood vessel. When a blood clot forms in the large, deep veins of the upper thigh, it's called deep vein thrombosis. If such a clot breaks free, it can circulate through the bloodstream, pass through the heart and become lodged in arteries in the lung, causing a pulmonary embolism. Such a blockage can severely damage portions of the lungs, and multiple embolisms can even be fatal.

Blood and healing

More than a one-trick pony, your blood is a vital cog in the healing process

Think of blood as the body's emergency response team to an injury. Platelets emit signals that encourage blood vessels to contract, stemming blood loss. The platelets then collect around the wound, reacting with a protein in plasma to form fibrin, a tissue that weaves into a mesh. Blood flow returns and white blood cells begin their hunt for bacteria. Fibroblasts create beds of fresh collagen and capillaries to fuel skin cell growth. The scab begins to contract, pulling the growing skin cells closer together until damaged tissue is replaced.

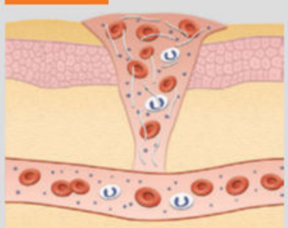
STAGE 1



INJURY

When the skin surface is cut, torn or scraped deeply enough, blood seeps from broken blood vessels to fill the wound. To stem the flow of bleeding, the blood vessels around the wound constrict.

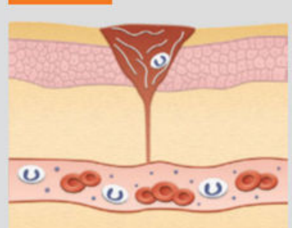
STAGE 2



HAEMOSTASIS

Activated platelets aggregate around the surface of the wound, stimulating vasoconstriction. Platelets react with a protein in plasma to form fibrin, a web-like mesh of stringy tissue.

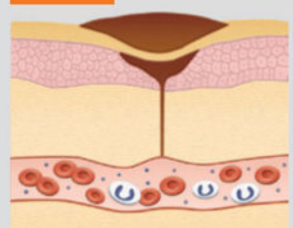
STAGE 3



INFLAMMATORY STAGE

Once the wound is capped with a drying clot, blood vessels open up again, releasing plasma and white blood cells into the damaged tissue. Macrophages digest harmful bacteria and dead cells.

STAGE 4



PROLIFERATIVE STAGE

Fibroblasts lay fresh layers of collagen inside the wound and capillaries begin to supply blood for the forming of new skin cells. Fibrin strands and collagen pull the sides of the wound together.

Inside a blood vessel

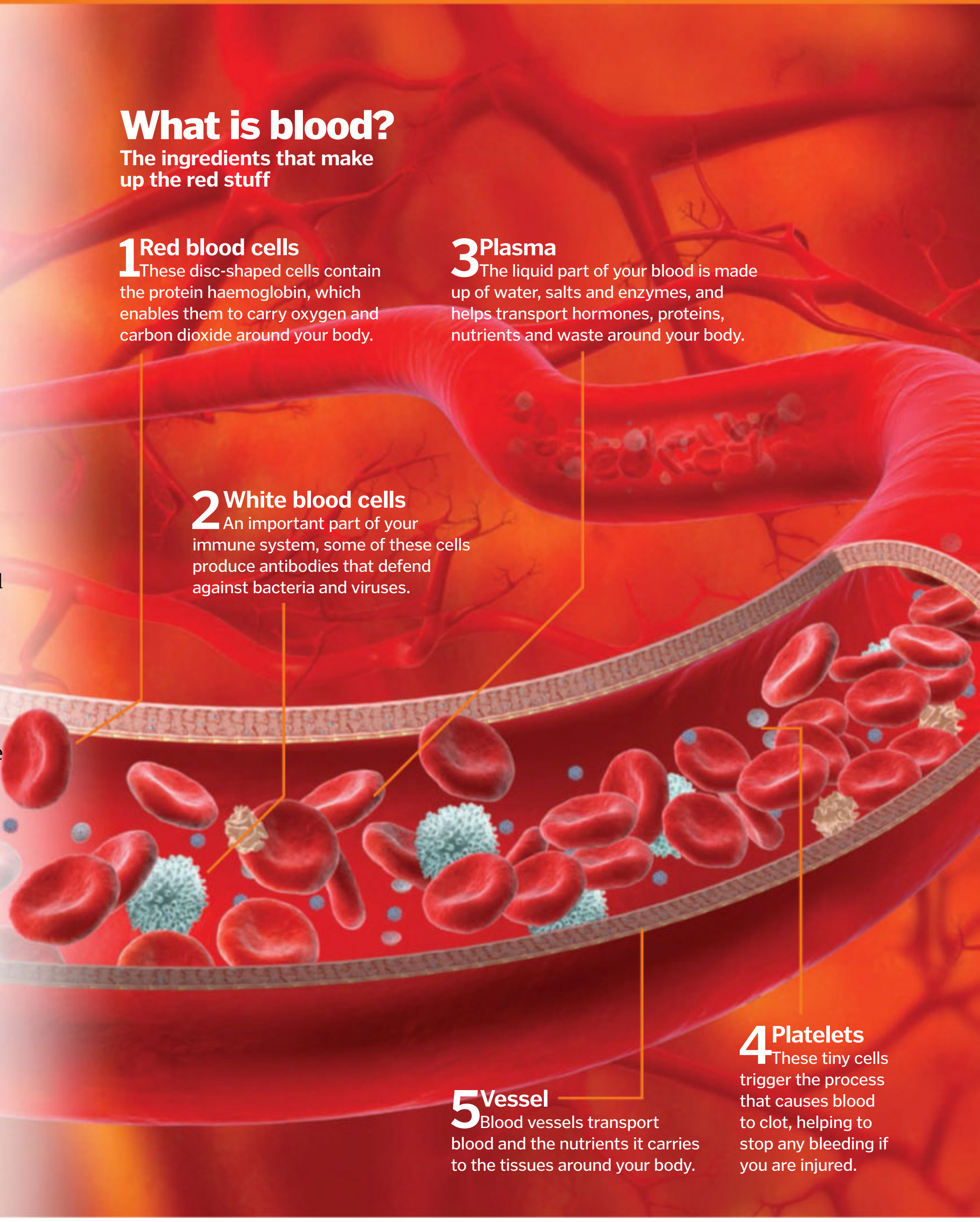
Discover what happens every time your heart beats

Inside your body there is a vast network of blood vessels that, if laid end to end, could easily wrap twice around the Earth. They are an important part of your circulatory system, carrying the equivalent of more than 14,000 litres of blood around your body every day to transport vital nutrients to where they are needed.

There are five main types of blood vessel. In general, arteries carry oxygenated blood away from the heart and have special elastic fibres in their walls to help squeeze it along when the heart muscle relaxes. The arteries then branch off into arterioles, which pass the blood into the capillaries, tiny blood vessels that transport nutrients from the blood into the body's tissues via their very thin walls.

As well as nourishing the tissue cells, capillaries also remove their waste products, passing the now deoxygenated blood on to the venules. These vessels drain the blood into the veins, which, with the help of valves that stop the blood flowing in the reverse direction, carry it back to the heart where it can pick up more oxygen.

In contrast to the other blood vessels in the body, the pulmonary artery takes deoxygenated blood from the heart to the lungs, where it is oxygenated and carried back to the heart via the pulmonary veins.



What is hyperventilation?

Find out why it's not always best to reach for the paper bag

Also known as over-breathing, hyperventilation is a common side effect of a panic attack or strong feelings of anxiety. When you feel breathless, you breathe more rapidly in an attempt to get more oxygen into your system. However, rather than increasing the levels of oxygen in your blood, this instead causes the carbon dioxide levels to decrease. As a result, the pH of your blood becomes more alkaline, causing the red blood cells to cling on to their oxygen instead of passing it on to the tissue cells as they would normally. This simply exacerbates the problem, causing you to try to breathe in more oxygen and lowering your carbon dioxide levels further.

One way to stop the vicious cycle is to breathe into a paper bag, forcing you to re-breathe some of your exhaled carbon dioxide. However, this will only work if the hyperventilation was brought on by anxiety or a panic attack. Over-breathing can also be caused by asthma, infections, bleeding or heart attacks, and in these cases, increased levels of carbon dioxide are dangerous. Therefore, the best course of treatment is to try to stay calm and slow your breathing, and seek medical help if the problem persists.


Breathing into a paper bag can be a dangerous way to treat hyperventilation

Tracheotomy surgery

Discover the science and tech behind this life-saving procedure

If the upper airway is blocked, by trauma, cancer or inflammation, an alternative route must be found for air to enter the lungs.

Planned tracheotomies are performed under general anaesthesia or sedation. The neck is extended backwards to allow the surgeon to easily identify the structures in the throat and to make an accurate incision (see diagram). First, a vertical cut is made in the skin, below the tracheal cartilage, and the underlying muscle and blood vessels are carefully moved out of the way to expose the trachea.

The trachea is normally held open by C-shaped rings of cartilage, which prevent the airway from collapsing. A hole is made between the third and fourth rings, allowing the surgeon access to the airway without disrupting the cartilage supports. A tracheotomy tube is then inserted into the airway and secured to the neck. If the tracheal opening is going to be a permanent feature rather than temporary then a piece of cartilage may be removed to allow the tube to sit more comfortably.

The vocal cords sit just behind the tracheal cartilage, above the tracheotomy incision site, but in order to talk, air must be able to pass through the vocal cords to make them vibrate. Some tracheotomy tubes contain unidirectional valves, enabling the patient to breathe in through the tube and out through their mouth, which provides good air supply to the lungs, without hampering speech.

If the patient is unable to breathe unaided, a ventilator may be attached to mechanically move air in and out of the lungs.

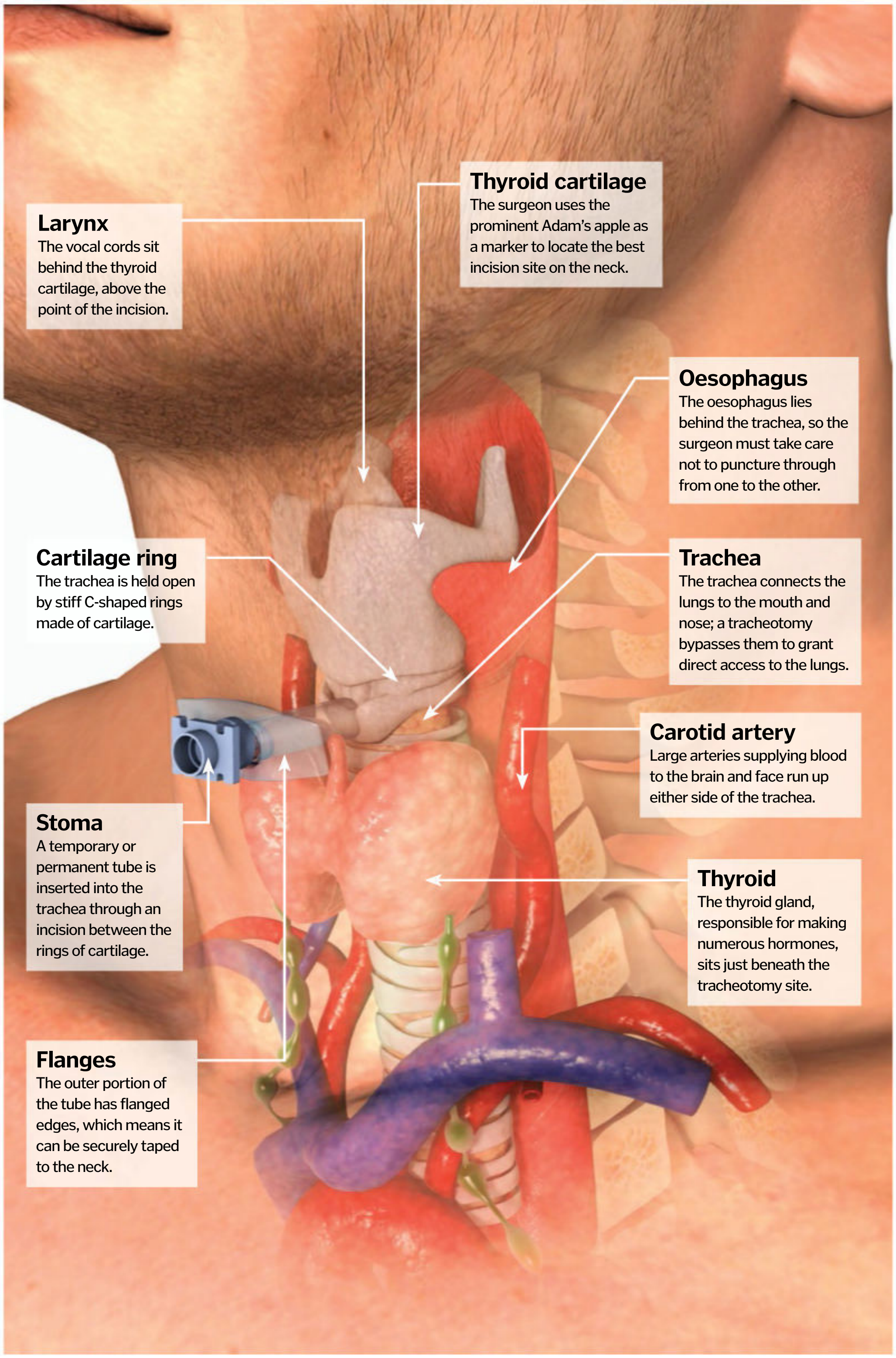
Have you got a pen?

A tracheotomy is a complex procedure, so in life-threatening, emergency situations a faster procedure – known as a cricothyrotomy (also called cricothyroidotomy) – may be performed. A higher incision is made just below the thyroid cartilage (Adam's apple) and then through the cricothyroid membrane, directly into the trachea.

It is possible to perform this procedure with a sharp instrument and any hollow tube, such as a straw or a ballpoint pen case. However, finding the correct location to make the incision is challenging, and without medical training there is great risk of damaging major blood vessels, the oesophagus or the vocal cords.

Anatomy of a tracheotomy

The trachea is surrounded by a minefield of major blood vessels, nerves, glands and muscles



Thyroid cartilage
The surgeon uses the prominent Adam's apple as a marker to locate the best incision site on the neck.

Larynx
The vocal cords sit behind the thyroid cartilage, above the point of the incision.

Oesophagus
The oesophagus lies behind the trachea, so the surgeon must take care not to puncture through from one to the other.

Cartilage ring
The trachea is held open by stiff C-shaped rings made of cartilage.

Trachea
The trachea connects the lungs to the mouth and nose; a tracheotomy bypasses them to grant direct access to the lungs.

Carotid artery
Large arteries supplying blood to the brain and face run up either side of the trachea.

Stoma
A temporary or permanent tube is inserted into the trachea through an incision between the rings of cartilage.

Thyroid
The thyroid gland, responsible for making numerous hormones, sits just beneath the tracheotomy site.

Flanges
The outer portion of the tube has flanged edges, which means it can be securely taped to the neck.

Hormones

How the human endocrine system develops and controls the human body

The glands in the endocrine system use chemicals called hormones to communicate with and control the cells and organs in our bodies. They are ductless glands that secrete different types of hormone directly into the bloodstream and target specific organs.

The target organs contain hormone receptors that respond to the chemical instructions supplied by the hormone. There are 50 different types of hormone in the body and they consist of three basic types: peptides, amines and steroids.

Steroids include the testosterone hormone. This is secreted by the cortex of the adrenal gland, the male and female reproductive organs and by the placenta in pregnant women. The majority of hormones are peptides that consist of short chains of amino acids. They are secreted by the pituitary and parathyroid glands. Amine hormones are secreted by the thyroid and adrenal medulla and are related to the fight or flight response.

The changes that are caused by the endocrine system act more slowly than the nervous system as they regulate growth, moods, metabolism, reproductive processes and a relatively constant stable internal environment for the body (homeostasis). The pituitary, thyroid and adrenal glands combine to form the major elements of the body's endocrine system along with various other elements such as the male testes, the female ovaries and the pancreas.

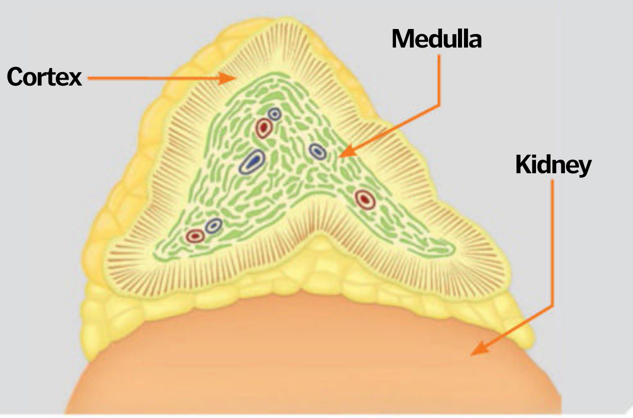
"Amine hormones are secreted by the thyroid and adrenal medulla"

Adrenal gland

We have two adrenal glands that are positioned on top of both kidneys. The triangular-shaped glands each consist of a two-centimetre thick outer cortex that produces steroid hormones, which include testosterone, cortisol and aldosterone.

The ellipsoid shaped, inner part of the gland is known as the medulla, which produces noradrenaline and adrenaline. These hormones increase the heart rate, and the body's levels of oxygen and glucose while reducing non-essential body functions.

The adrenal gland is known as the 'fight or flight' gland as it controls how we respond to stressful situations, and prepares the body for the demands of either fighting or running away as fast as you can. Prolonged stress over-loads this gland and causes illness.



The endocrine system

Hypothalamus
Releases hormones to the pituitary gland to promote its production and secretion of hormones to the rest of the body.

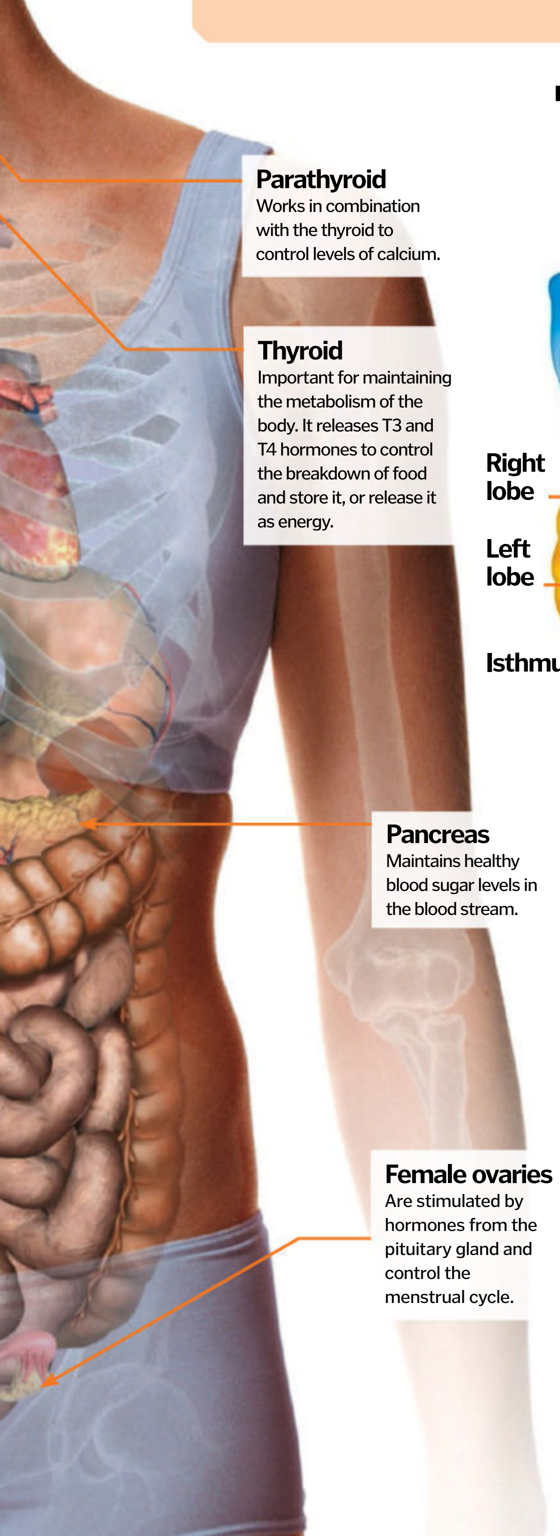
Pituitary gland
Releases hormones to the male and female reproductive organs and to the adrenal glands. Stimulates growth in childhood and maintains adult bone and muscle mass.

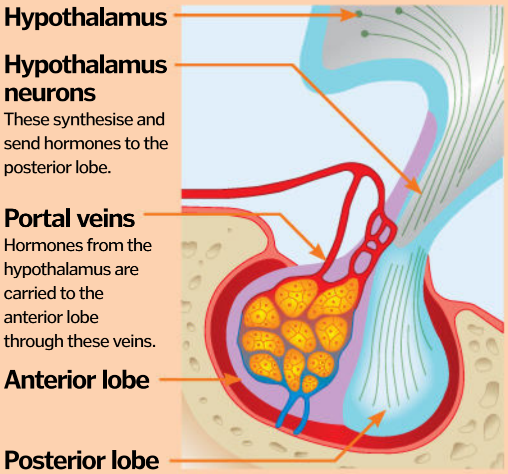
Pineal gland
Secretes melatonin, which controls sleep patterns and controls the production of hormones related to the reproductive organs.

Thymus
Is part of the immune system. It produces thymosins that control the behaviour of white blood T-cells.

Adrenal glands
Controls the burning of protein and fat, and regulates blood pressure. The medulla secretes adrenaline to stimulate the fight or flight response.

Male testes
These two glands produce testosterone that is responsible for sperm production, muscle and bone mass and sex drive.





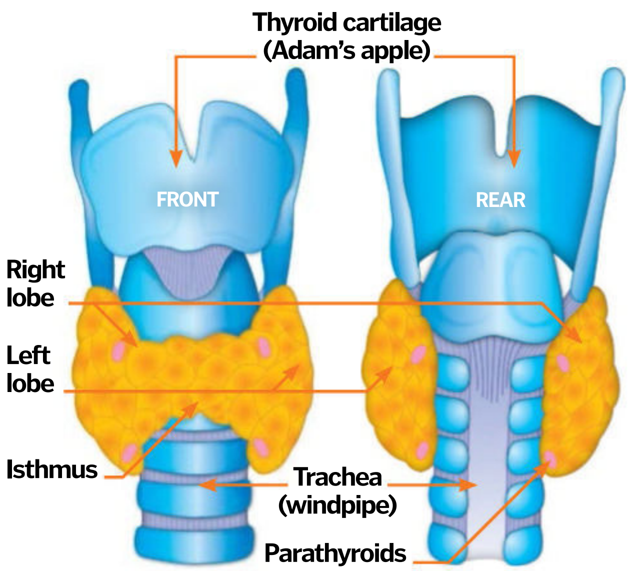
Pituitary gland

The pea-sized pituitary gland is a major endocrine gland that works under the control of the hypothalamus. The two organs inside the brain work in concert and mediate feedback loops in the endocrine system to maintain control and stability within the body.

The pituitary gland features an anterior (front) lobe and a posterior (rear) lobe. The anterior lobe secretes growth hormones that stimulate the development of the muscles and bones; it also stimulates the development of ovarian follicles in the female ovary. In males, it stimulates the production of sperm cells. The posterior lobe stores vasopressin and oxytocin that is supplied by the hypothalamus. Vasopressin allows the retention of water in the kidneys and suppresses the need to excrete urine. It also raises blood pressure by contracting the blood vessels in the heart and lungs.

Oxytocin influences the dilation of the cervix before giving birth and the contraction of the uterus after birth. The lactation of the mammary glands are stimulated by oxytocin when mothers begin to breastfeed.

Thyroid and parathyroids



The two lobes of the thyroid sit on each side of the windpipe and are linked together by the isthmus that runs in front of the windpipe. It stimulates the amount of body oxygen and energy consumption, thereby keeping the metabolic rate of the body at the current levels to keep you healthy and active.

The hypothalamus and the anterior pituitary gland are in overall control of the thyroid and they respond to changes in the body by either suppressing or increasing thyroid stimulating hormones. Overactive thyroids cause excessive sweating, weight loss and sensitivity to heat, whereas underactive thyroids cause sensitivity to hot and cold, baldness and weight gain. The thyroid can swell during puberty and pregnancy or due to viral infections or lack of iodine in a person's diet.

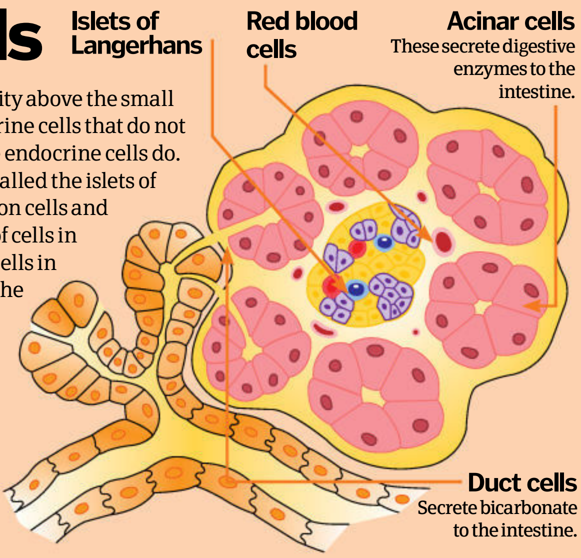
The four small parathyroids regulate the calcium levels in the body; it releases hormones when calcium levels are low. If the level of calcium is too high the thyroid releases calcitonin to reduce it. Therefore, the thyroid and parathyroids work in tandem.

Pancreatic cells

The pancreas is positioned in the abdominal cavity above the small intestine. It consists of two types of cell, the exocrine cells that do not secrete their output into the bloodstream but the endocrine cells do.

The endocrine cells are contained in clusters called the islets of Langerhans. They number approximately 1 million cells and are only one or two per cent of the total number of cells in the pancreas. There are four types of endocrine cells in the pancreas. The beta cells secrete insulin and the alpha cells secrete glucagon, both of which stimulate the production of blood sugar (glucose) in the body. If the Beta cells die or are destroyed it causes type 1 diabetes, which is fatal unless treated with insulin injections.

The other two cells are the gamma and delta cells. The former reduces appetite and the latter reduces the absorption of food in the intestine.



Exploring the sensory system

The complex senses of the human body and how they interact is vital to the way we live day to day

The sensory system is what enables us to experience the world. It can also warn us of danger, trigger memories and protect us from damaging stimuli, such as hot surfaces. The sensory system is highly developed, with many components detecting both physical and emotional properties of the environment. For example, it can interpret chemical molecules in the air into smells, moving molecules of sound into noises and pressure placed on the skin into touch. Indeed, some of our senses are so finely tuned they allow reactions within milliseconds of detecting a new sensation.

The five classic senses are sight, hearing, smell, taste and touch. We need senses not only to interpret the world around us, but also to function within it. Our senses enable us to modify our movements and thoughts, and sometimes they directly feed signals into muscles. The sensory nervous system that lies behind this is made up of receptors, nerves and dedicated parts of the brain.

There are thousands of different stimuli that can trigger our senses, including light, heat, chemicals in food and pressure. These 'stimulus modalities' are then detected by specialised receptors, which convert them into sensations such as hot and cold, tastes, images and touch. The incredible receptors – like the eyes, ears, nose, tongue and skin – have adapted over time to work seamlessly together and without having to be actively 'switched on'.

However, sometimes the sensory system can go wrong. There are hundreds of diseases of the senses, which can have both minor effects, or a life-changing impact. For example, a blocked ear can affect your balance, or a cold your ability to smell – but these things don't last for long.

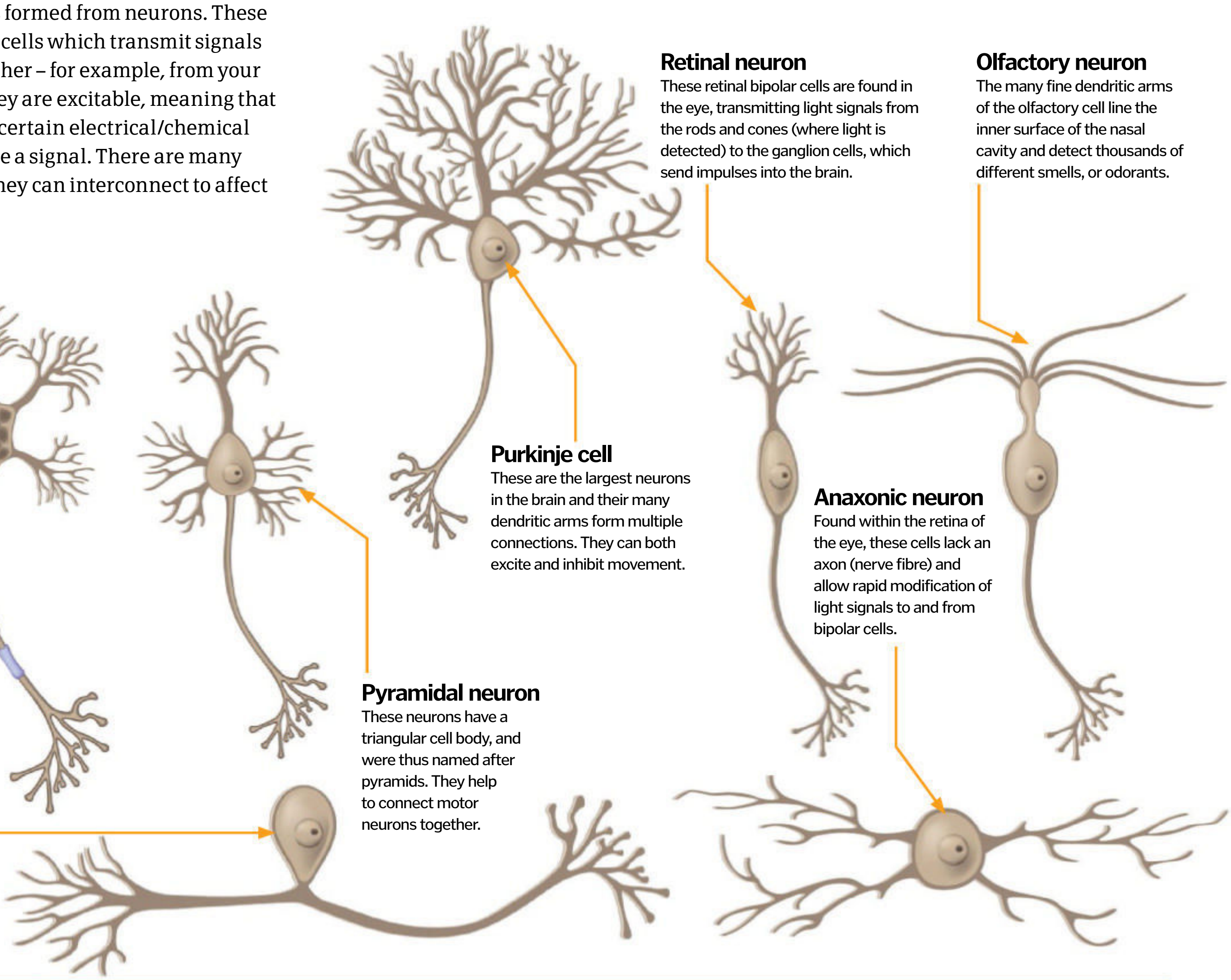
In contrast, say, after a car accident severing the spinal cord, the damage can be permanent. There are some very specific problems that the sensory system can bring as well. After an amputation, the brain can still detect signals from the nerves that used to connect to the lost limb. These sensations can cause excruciating pain; this particular condition is known as phantom limb syndrome.

However the sensory system is able to adapt to change, with the loss of one often leading to others being heightened. Our senses normally function to gently inhibit each other in order to moderate individual sensations. The loss of sight from blindness is thought to lead to strengthening of signals from the ears, nose and tongue. Having said this, it's certainly not universal among the blind, being more common in people who have been blind since a young age or from birth. Similarly, some people who listen to music like to close their eyes, as they claim the loss of visual input can enhance the audio experience.

Although the human sensory system is well developed, many animals out-perform us. For example, dogs can hear much higher-pitched sounds, while sharks have a far better sense of smell – in fact, they can sniff out a single drop of blood in a million drops of water!

Body's messengers

The sensory system is formed from neurons. These are specialised nerve cells which transmit signals from one end to the other – for example, from your skin to your brain. They are excitable, meaning that when stimulated to a certain electrical/chemical threshold they will fire a signal. There are many different types, and they can interconnect to affect each other's signals.



Retinal neuron
These retinal bipolar cells are found in the eye, transmitting light signals from the rods and cones (where light is detected) to the ganglion cells, which send impulses into the brain.

Olfactory neuron
The many fine dendritic arms of the olfactory cell line the inner surface of the nasal cavity and detect thousands of different smells, or odorants.

Purkinje cell
These are the largest neurons in the brain and their many dendritic arms form multiple connections. They can both excite and inhibit movement.

Anaxonic neuron
Found within the retina of the eye, these cells lack an axon (nerve fibre) and allow rapid modification of light signals to and from bipolar cells.

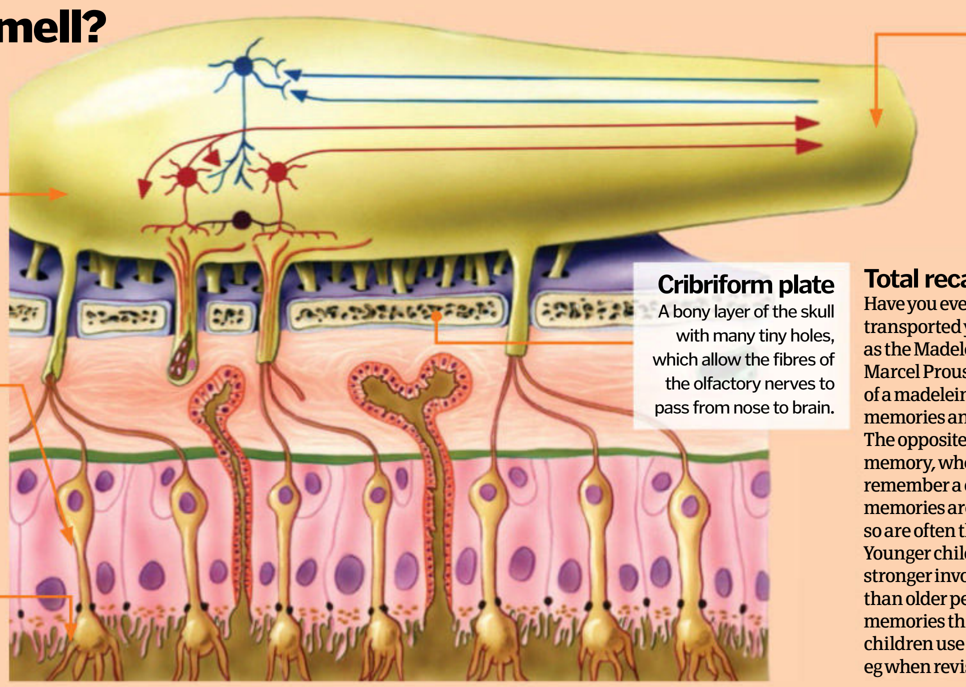
Motor neuron
These fire impulses from the brain to the body's muscles, causing contraction and thus movement. They have lots of extensions (ie they are multipolar) to spread the message rapidly.

Pyramidal neuron
These neurons have a triangular cell body, and were thus named after pyramids. They help to connect motor neurons together.

Unipolar neuron
These sensory neurons transduce a physical stimulus (for example, when you are touched) into an electrical impulse.

How do we smell?

Find out how our nose and brain work together to distinguish scents



Olfactory bulb
Containing many types of cell, olfactory neurons branch out of here through the cribriform plate below.

Olfactory neuron
These neurons are highly adapted to detect a wide range of different odours.

Olfactory epithelium
Lining the nasal cavity, this layer contains the long extensions of the olfactory neurons and is where chemical molecules in air trigger an electric impulse.

Olfactory nerve
New signals are rapidly transmitted via the olfactory nerve to the brain, which collates the data with sight and taste.

Cribriform plate
A bony layer of the skull with many tiny holes, which allow the fibres of the olfactory nerves to pass from nose to brain.

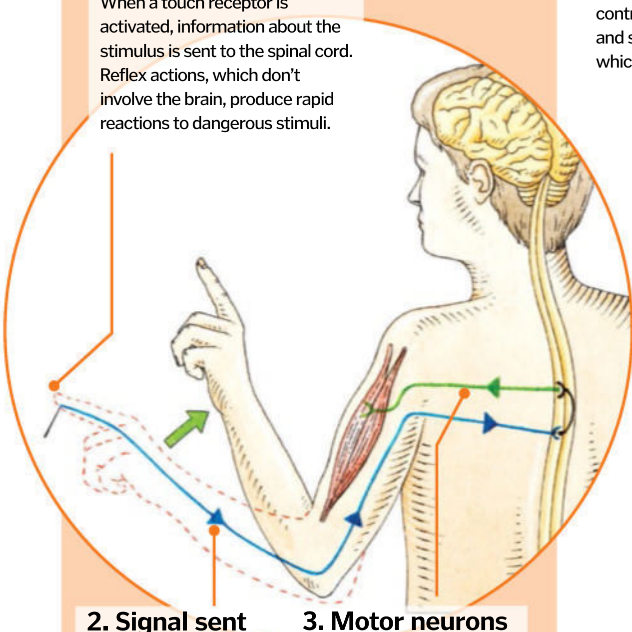
Total recall

Have you ever smelt something that transported you back in time? This is known as the Madeleine effect because the writer Marcel Proust once described how the scent of a madeleine cake suddenly evoked strong memories and emotions from his childhood. The opposite type of recall is voluntary memory, where you actively try and remember a certain event. Involuntary memories are intertwined with emotion and so are often the more intense of the two. Younger children under the age of ten have stronger involuntary memory capabilities than older people, which is why these memories thrust you back to childhood. Older children use voluntary memory more often, eg when revising for exams.

Understanding lightning reflexes

Have you ever felt something scorching hot or freezing cold, and pulled your hand away without even thinking about it? This reaction is a reflex. Your reflexes are the most vital and fastest of all your senses. They are carried out by the many ‘reflex arcs’ located throughout the body.

For example, a temperature-detecting nerve in your finger connects to a motor nerve in your spine, which travels straight to your biceps, creating a circular arc of nerves. By only having two nerves in the circuit, the speed of the reflex is as fast as possible. A third nerve transmits the sensation to the brain, so you know what’s happened, but this nerve doesn’t interfere with the arc; it’s for your information only. There are other reflex arcs located within your joints, so that, say, if your knee gives way or you suddenly lose balance, you can compensate quickly.



1. Touch receptor

When a touch receptor is activated, information about the stimulus is sent to the spinal cord. Reflex actions, which don’t involve the brain, produce rapid reactions to dangerous stimuli.

2. Signal sent to spine

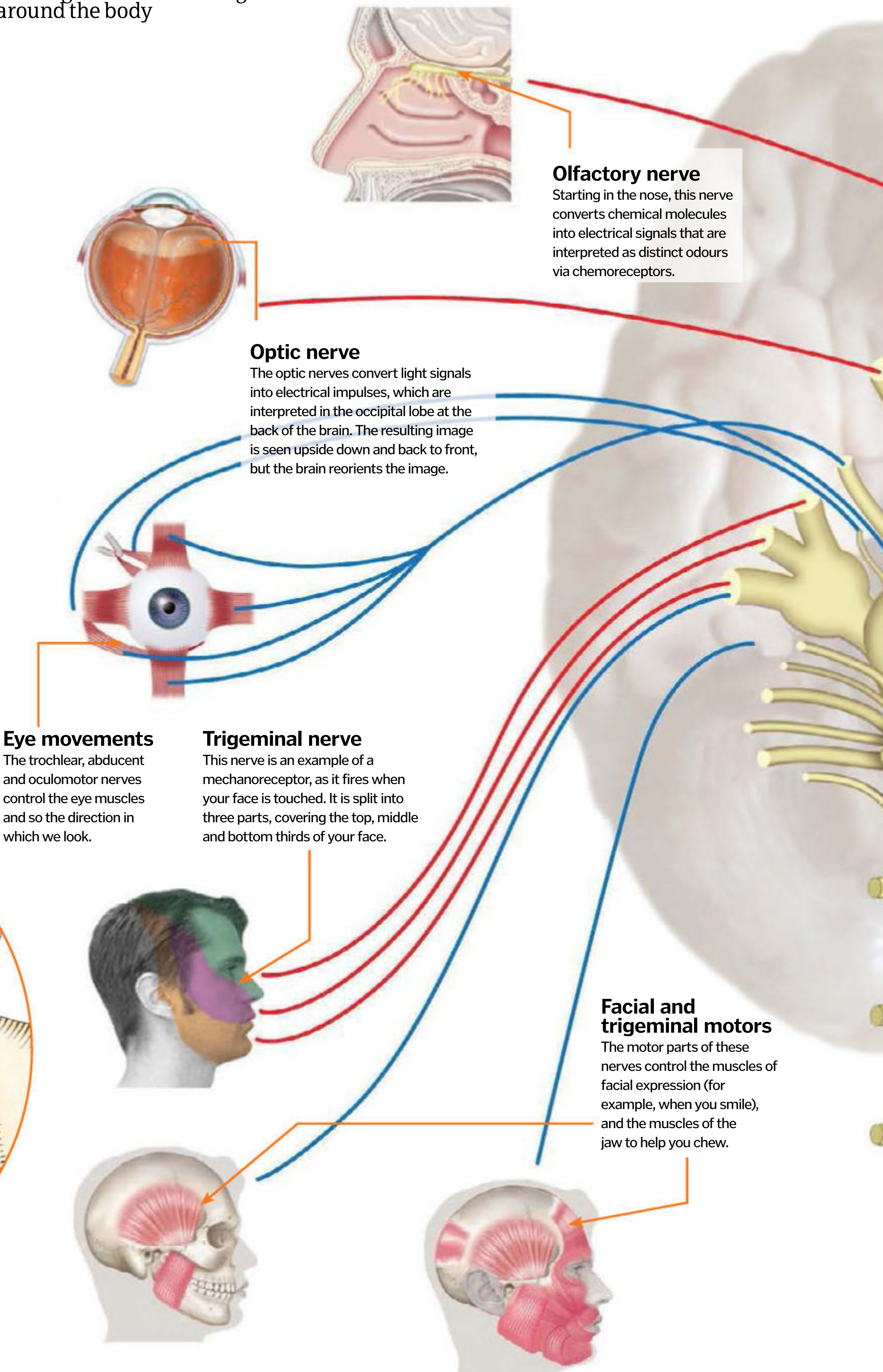
When sensory nerve endings fire, information passes through nerve fibres to the spinal cord.

3. Motor neurons feed back

The signals trigger motor neurons that initiate their own impulses that feed back to the muscle, telling it to move the body part.

Key nerves

These transmit vital sensory information to our brain while also sending motor function signals all around the body



Olfactory nerve

Starting in the nose, this nerve converts chemical molecules into electrical signals that are interpreted as distinct odours via chemoreceptors.

Optic nerve

The optic nerves convert light signals into electrical impulses, which are interpreted in the occipital lobe at the back of the brain. The resulting image is seen upside down and back to front, but the brain reorients the image.

Eye movements

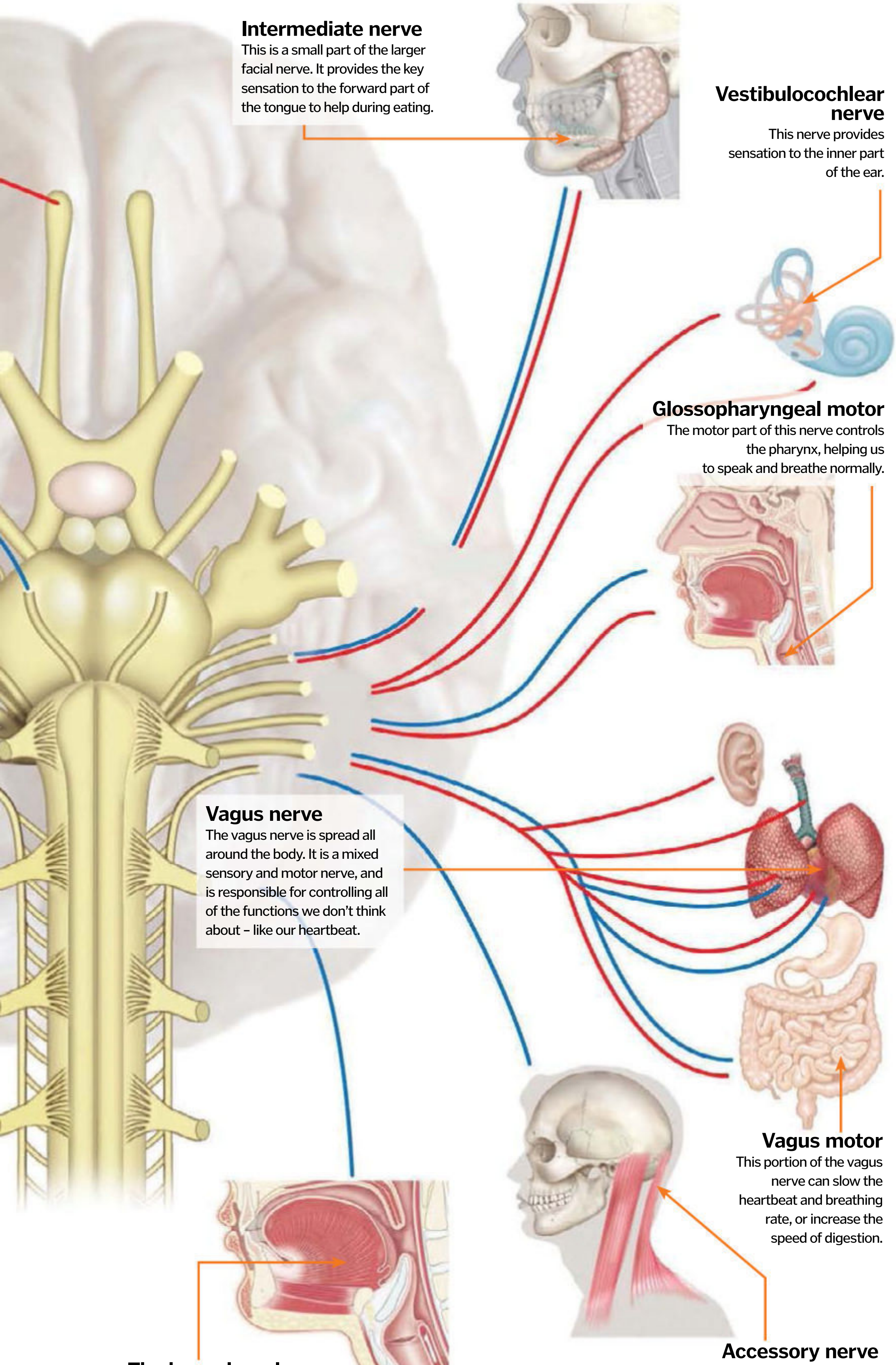
The trochlear, abducent and oculomotor nerves control the eye muscles and so the direction in which we look.

Trigeminal nerve

This nerve is an example of a mechanoreceptor, as it fires when your face is touched. It is split into three parts, covering the top, middle and bottom thirds of your face.

Facial and trigeminal motors

The motor parts of these nerves control the muscles of facial expression (for example, when you smile), and the muscles of the jaw to help you chew.



Intermediate nerve
This is a small part of the larger facial nerve. It provides the key sensation to the forward part of the tongue to help during eating.

Vestibulocochlear nerve
This nerve provides sensation to the inner part of the ear.

Glossopharyngeal motor
The motor part of this nerve controls the pharynx, helping us to speak and breathe normally.

Vagus nerve
The vagus nerve is spread all around the body. It is a mixed sensory and motor nerve, and is responsible for controlling all of the functions we don't think about – like our heartbeat.

Vagus motor
This portion of the vagus nerve can slow the heartbeat and breathing rate, or increase the speed of digestion.

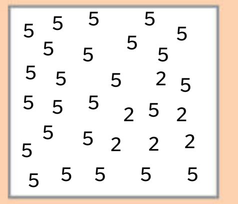
The hypoglossal nerve
This nerve controls the movements of the tongue.

Accessory nerve
Connecting the muscles of the neck to the brain, this nerve lets us turn our heads from side to side.

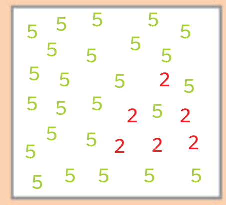
Crossed senses

Synaesthesia is a fascinating, if yet completely understood, condition. In some people, two or more of the five senses become completely linked so when a single sensation is triggered, all the linked sensations are activated too. For example, the letter 'A' might always appear red, or seeing the number '1' might trigger the taste of apples. Sights take on smells, a conversation can take on tastes and music can feel textured.

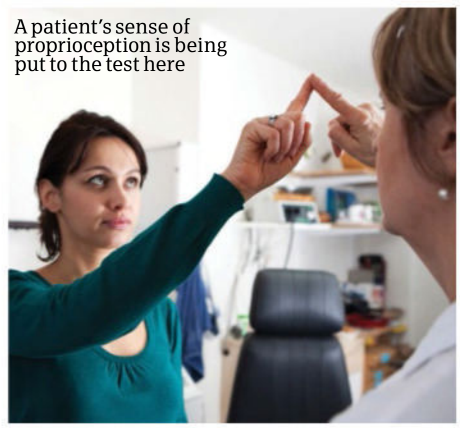
People with synaesthesia certainly don't consider it to be a disorder or a disease. In fact, many do not think what they sense is unusual, and they couldn't imagine living without it. It often runs in families and may be more common than we think. More information about the condition is available from the UK Synaesthesia Association (**www.uksynaesthesia.com**).



Non-synaesthetes struggle to identify a triangle of 2s among a field of number 5s.



But a synaesthete who sees 2s as red and 5s as green can quickly pick out the triangle.



A patient's sense of proprioception is being put to the test here

Is there really a 'sixth sense'?

Our sense of balance and the position of our bodies in space are sensations we rarely think about and so are sometimes thought of as a 'sixth sense'. There is a whole science behind them though, and they are collectively called proprioception. There are nerves located throughout the musculoskeletal system (for example, within your muscles, tendons, ligaments and joints) whose job it is to send information on balance and posture back to the brain. The brain then interprets this information rapidly and sends instructions back to the muscles to allow for fine adjustments in balance. Since you don't have to think about it and you can't switch it off, you don't know how vital these systems are until they're damaged. Sadly some medical conditions, including strokes, can affect our sense of proprioception, making it difficult to stand, walk, talk and move our limbs.

Understanding chickenpox

Discover the biology behind the infamous childhood ailment and why it never really goes away…

Chickenpox is a strain of the Varicella zoster virus, which many of us have experienced during our youth. Most prominent in children, the virus is contracted through coughing and sneezing or transferred on shared objects, which makes schools a prime location.

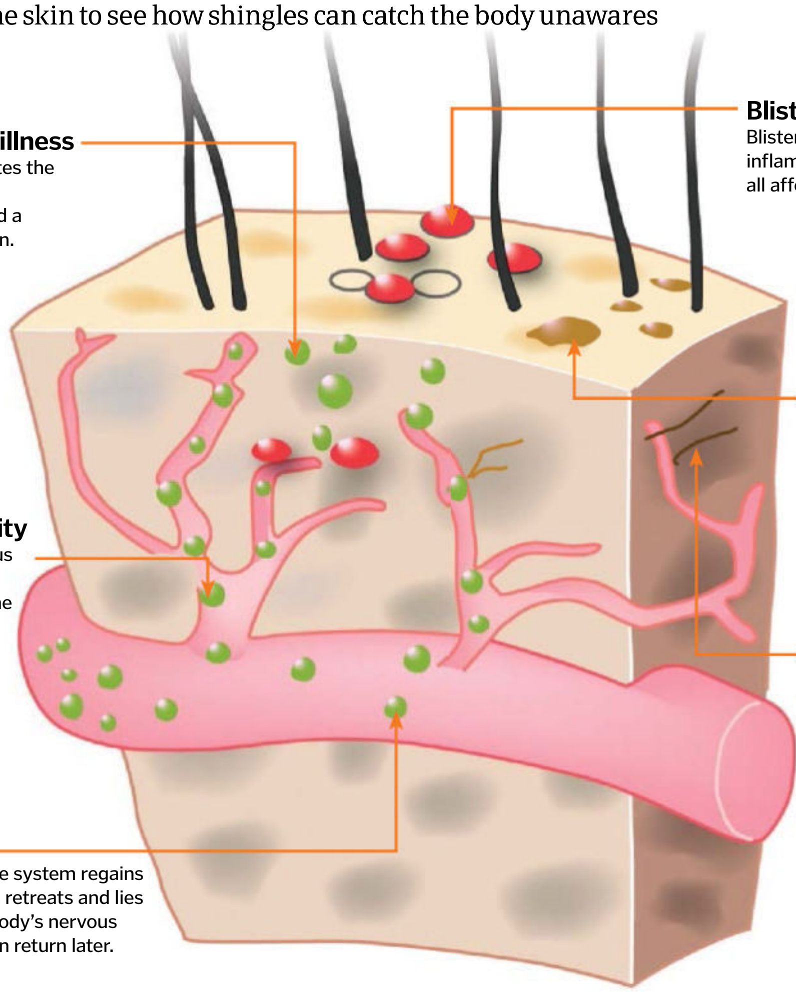
The most famous symptom is the appearance of small itchy red spots, which vary in size from 10-20 millimetres (0.4-0.8 inches) across. The extent can vary but in most cases they cover the face, arms, legs, stomach and back. These develop into fluid-filled blisters and are often accompanied by a fever. The blisters burst, scab over and fall off within a few days, but new waves of spots can emerge to replace them; it usually takes one to two weeks for the body to regain control. Chickenpox is rarely serious but it is important not to interfere with the scabs as infection can make it more severe.

A vaccine is only offered in extreme circumstances when an individual may have a weak immune system or be particularly vulnerable to the disease.

After the outbreak, chickenpox doesn't disappear entirely. The disease lies in a dormant state within the body as your immune system keeps it under wraps. The infection can break out again later and reappear as shingles. A rash builds up on a certain point of the body and the symptoms return, most commonly in people over 50. On average, three in every 1,000 people contract shingles in the UK each year.

When chickenpox strikes back…

Get under the skin to see how shingles can catch the body unawares



Start of the illness
The virus infiltrates the skin and causes inflammation and a burning sensation.

Blisters emerge
Blisters become visible and inflamed rashes appear on all affected areas.

Don't scratch!
The blisters then harden into scabs and fall off. Scratching at the spots makes the healing process slower.

Low immunity
The Varicella virus becomes active when the immune system is weak, overcoming the body's natural defences.

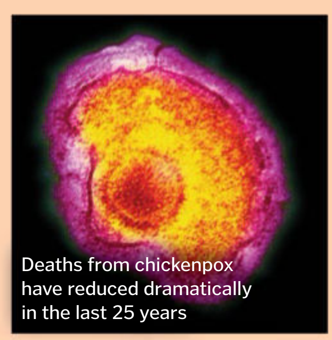
Future effects
In around 10-20 per cent of people who have shingles, the nerve fibres become damaged which can lead to postherpetic neuralgia (nerve pain).

Dormancy
Once the immune system regains control, the virus retreats and lies dormant in the body's nervous system, but it can return later.

Grown-up chickenpox

90 per cent of adults are immune if they've had the disease as a child but it still affects adults and teenagers. If you develop chickenpox at a later age, all the symptoms are more severe, with more chronic pain, headaches and sore throats; therefore, there is greater need for treatment, such as pain relief and soothing creams.

The disease tends to affect adults more dramatically as it can now mutate into a variety of other strains, such as shingles or, in extreme cases, lead to encephalitis, postherpetic neuralgia or pneumonia. However, the chances of this happening are only around ten per cent.



Deaths from chickenpox have reduced dramatically in the last 25 years

Why do we cry?

Find out how our tears have been helping to protect us since the dawn of time

Whether it's a sad film, a joyous reunion or simply that you've just banged your knee on a coffee table, everyone has cried at some point in their life. But why have we evolved to do it?

There's a theory that it stems right back as far as our pre-evolved days, where tears streaming down our primitive eyes and blurring our vision was a sign of surrender, proving that we meant our aggressor no harm.

But moving on to the present day, the science shows that there are a number of sound biological reasons for tearing up.

There are reflex tears, the stream caused by getting smoke or sulphenic acid from a chopped onion into your eye. When this happens, sensory nerves in your cornea send a signal to the brain that the eyes need protecting. The brain then releases hormones into the lacrimal glands located behind the eyelid, which produces tears to provide a layer of protection and to water down the irritant.

However, the more common form of crying is the emotional kind. When strong emotions are brought about – whether through happiness, sadness or pain – the brain's cerebrum is aware that you are undergoing a strong emotional reaction to a stimulus. The endocrine system releases a set of hormones to the lacrimal gland, which secretes liquid onto the eye. Excess water can escapes down the nose, via the tear ducts.

Studies of tears have shown there is a biochemical reason for emotional crying. While reflex tears are 98 per cent water, emotional tears contain several chemicals, including adrenocorticotropic hormones present in times of stress, and leucine-enkephalin – an endorphin that releases pain and improves your mood. Therefore, crying appears to be a way of releasing hormones and toxins that build up during times of intense emotion.

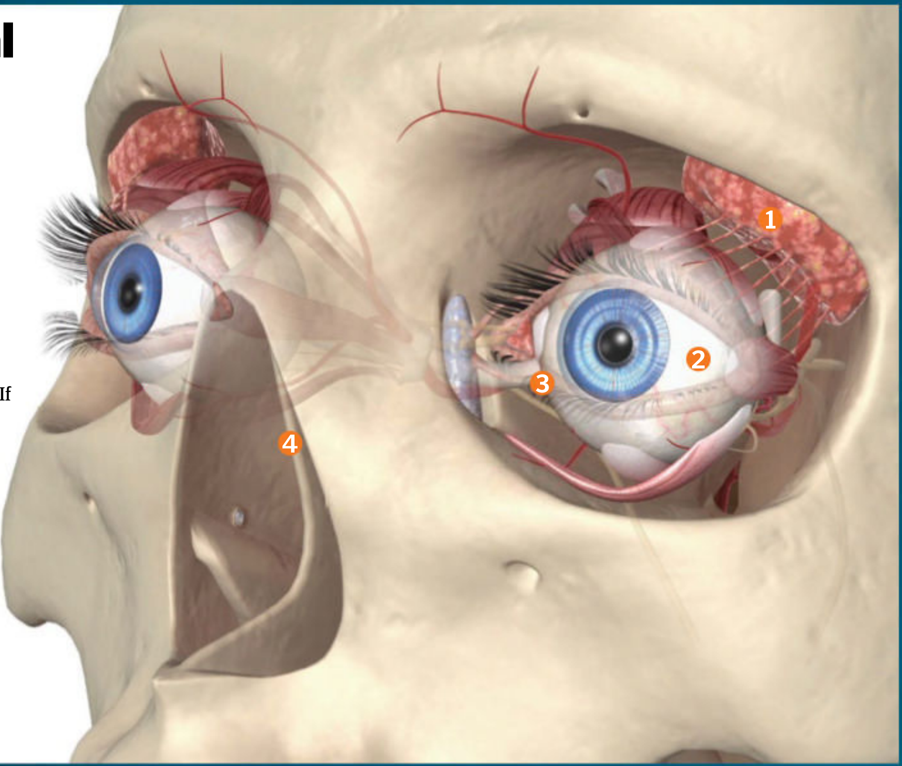
The lacrimal system

1 Lacrimal gland
This gland receives the message from the cerebrum to produce tears.

2 Cornea
Tears help protect the surface of the eye.

3 Tear ducts
This is where the water flows to. If there's too much, it flows down the face.

4 Runny nose
Tears that flow through the tear ducts go down a nasal passage, which is what causes a runny nose.



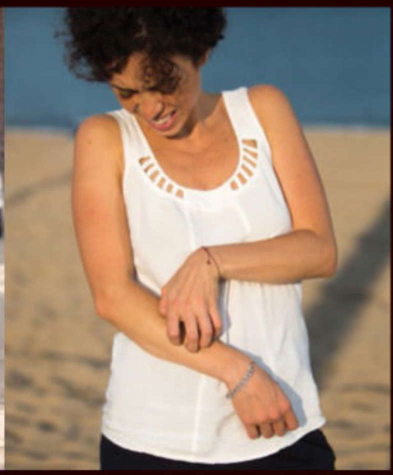
Battle of the sexes

While there is a stereotype that women are tearier than men, there is some science to explain the reasons behind this. Studies have shown that women cry about four times as often as men and, while there are cultural factors to be taken into consideration, there are biological factors too.
Until their adolescent years, boys and girls cry fairly equally. As testosterone levels rise in boys, they are more likely to get angry than upset. Meanwhile, girls gain increased oestrogen levels, which modifies endorphin production, often leading to more emotional responses to stimuli.

THE OTHER SENSES

Discover the ten senses you never knew you had



The five classic human senses get all of the attention, so it might surprise you to know that there are several more senses working quietly in the background. Take something as simple as sitting down to eat your dinner. All five senses are active, taking in the sight and smell of the food on your plate, the taste and feel as you put it into your mouth, and the sound as you chew, but without your other senses, the experience would not be the same.

The simple act of sitting at the table and getting the food from the plate to your mouth is a sensory feat. You can't keep an eye on your limbs all the time, so the positions of your joints and the tension on your muscles is constantly measured, enabling you to eat without having to closely watch what you are doing. In order to stay balanced as you reach across the table, sensory information is quietly gathered by specialist structures in the inner ear.

Once the food is inside your mouth, one set of sensors provide information about the temperature, and another set of specialist nerves called nociceptors quickly alert you if the mouthful is dangerously hot or cold. At the same time, your blood and the fluid surrounding your central nervous system are monitored to make sure that levels of carbon dioxide and oxygen remain within normal limits, and your breathing rate is subconsciously adjusted.

As your stomach starts to fill up, stretch sensors feed back to the brain, turning down the signals that are telling you to keep eating, and when the part-digested food starts to hit your small intestine, sensors trigger the production of a hormone that flicks the switch telling you that you have had enough. The build-up of waste products is also closely monitored, and long after your meal is completed, sensors will alert you when it is time to get rid of anything that is left over.

So while the traditional five senses are the ones that we rely on most in our conscious interactions with the world around us, there are several more that work quietly in the background as we go about our daily lives.

DID YOU KNOW? *Otolith is ancient Greek for 'ear stone' and describes the gravity-detecting crystals of calcium inside the ear*

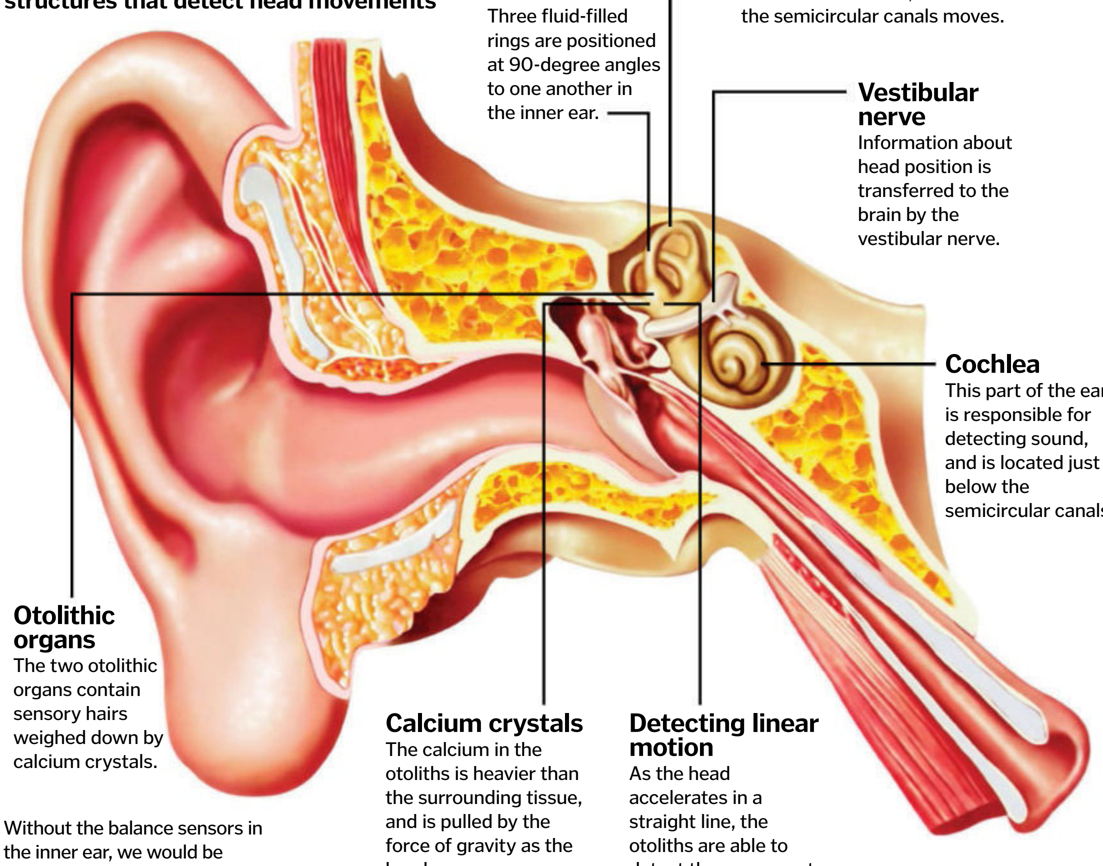
The brain uses a combination of signals from the eyes, ears, joints and muscles to maintain balance

Balance
(equilibrioception)

Our sense of balance is handled by the vestibular system in the inner ear, and provides vital feedback about head position and movement. Inside the ear there are three semicircular canals; each is filled with fluid. At one end of each canal is a bulge supporting a series of sensitive hairs. As you move your head, the fluid moves too, bending the tiny hairs and sending information about head rotation to the brain. There are also two organs called otoliths on each side of the head. These contain sensory hairs weighed down by calcium crystals that help to tell which way is up.

The sense of balance

The inner ear contains specialised structures that detect head movements



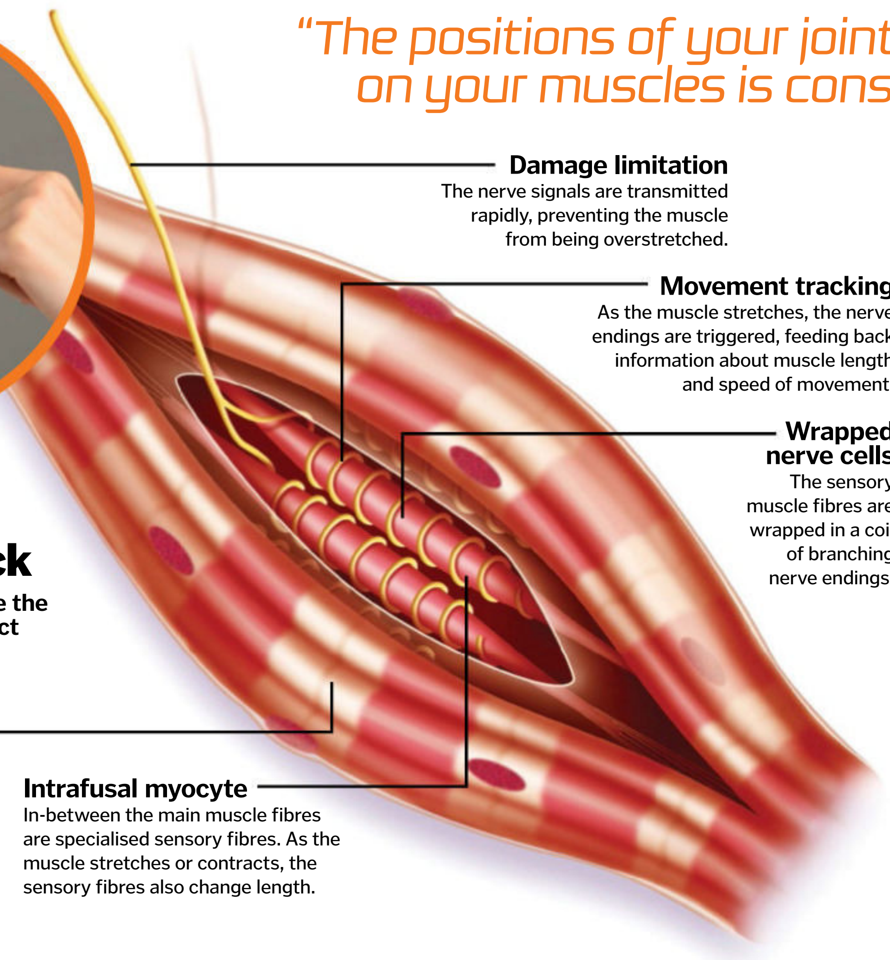
Without the balance sensors in the inner ear, we would be constantly dizzy and disorientated

"The positions of your joints and the tension on your muscles is constantly measured"

Without proprioception, you wouldn't be able to touch your nose with your eyes closed

Keeping track

Specialised fibres inside the muscle are able to detect stretch and movement



Movement
(proprioception)

Even the simplest movements would be a challenge without this sense; proprioception allows us to keep track of the position of our bodies in space without looking. This enables us to make the tiny adjustments that keep us from falling over when we are standing still, helps us to judge the distance each time we take a step, and allows us to coordinate complex movements like riding a bike or playing the piano. The receptors responsible are found in the joints, muscles and skin, and help to relay information about the angle and position of each joint, and the tension on our tendons and muscles, providing the brain with constant feedback.

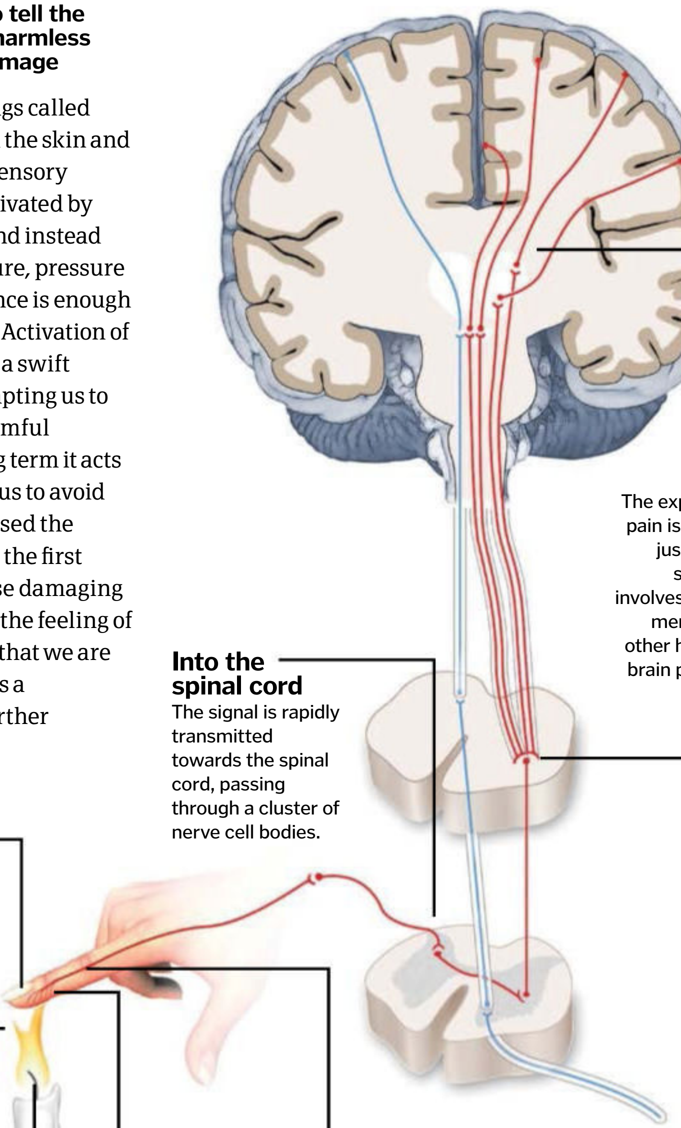
Pain
(nociception)

This sense allows us to tell the difference between a harmless touch and potential damage

Specialised nerve endings called nociceptors are found in the skin and organs. Unlike normal sensory nerves, these are not activated by low-level stimulation, and instead wait until the temperature, pressure or level of a toxic substance is enough to cause the body harm. Activation of these nerves can trigger a swift withdrawal reflex, prompting us to move away from the harmful stimulus, and in the long term it acts as a deterrent, teaching us to avoid whatever it was that caused the unpleasant sensation in the first place. The ability to sense damaging stimuli is different from the feeling of pain, and the sensation that we are all familiar with involves a significant amount of further processing in the brain.

How we feel pain

Detecting damage helps to keep our bodies safe



Pain
The experience of pain is more than just the nerve signals, and involves emotions, memories and other higher-level brain processing.

Into the spinal cord
The signal is rapidly transmitted towards the spinal cord, passing through a cluster of nerve cell bodies.

Pain receptor
Nociceptors are only activated if tissue damage is imminent, alerting the body to potential danger.

Heat
Some nerves respond specifically to heat, becoming active at temperatures above 40-45 degrees Celsius (104-113 degrees Fahrenheit).

Cold
Other nerves respond to cold temperatures, and start to fire when temperatures drop below five degrees Celsius (41 degrees Fahrenheit).

Pressure
Some nociceptors respond to pressure, triggering when parts of the body are dangerously compressed.

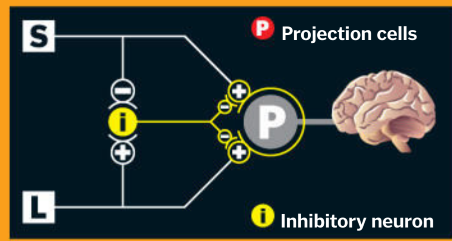
Chemical
Some nociceptors respond to chemical signals of tissue damage, like the presence of acid, or the lack of oxygen.

Towards the brain
The incoming signal can induce a rapid withdrawal reflex just by reaching the spinal cord, but the feeling of pain relies on signals travelling onwards to the brain.

"The ability to sense damaging stimuli is different from the feeling of pain"

Numbing the pain

Have you ever put your finger in your mouth after shutting it in a door, or grabbed hold of your foot after stubbing your toe? Incoming signals from our other senses can switch off pain signals, preventing some of them from reaching the brain.



Pain gate
Nociceptive (pain-detecting) nerves send their signals towards the spinal cord before they go on to the brain, but in order to reach the brain they have to travel through a biological gate.

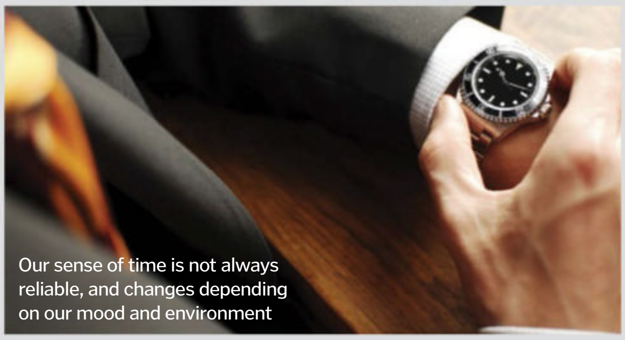
Inhibition of pain
Touch-sensitive nerves pass their messages through the same region as the pain signals. These nerve cells are larger and faster, and are able to close the gate, overriding the pain signals.

Pain signal
Without the input from the large nerve fibres, the gate is opened. This allows pain messages travelling along the smaller nerve fibres to pass through the spinal cord and onwards towards the brain.

Time (Chronoception)

Internal clocks help us to keep track of time

Even without a watch, we have a sense of the passage of time, but our body clock is not like any normal timepiece. The suprachiasmatic nucleus in the brain is the master clock, and it governs our daily cycle, or circadian rhythm. This 24-hour clock controls daily peaks and troughs in our hormone levels, influencing many behaviours, from eating to sleeping. For shorter tasks, scientists think that we might have several internal stopwatches keeping time inside our brains. As yet, the parts of the brain responsible for keeping these rhythms have not been discovered.



Our sense of time is not always reliable, and changes depending on our mood and environment

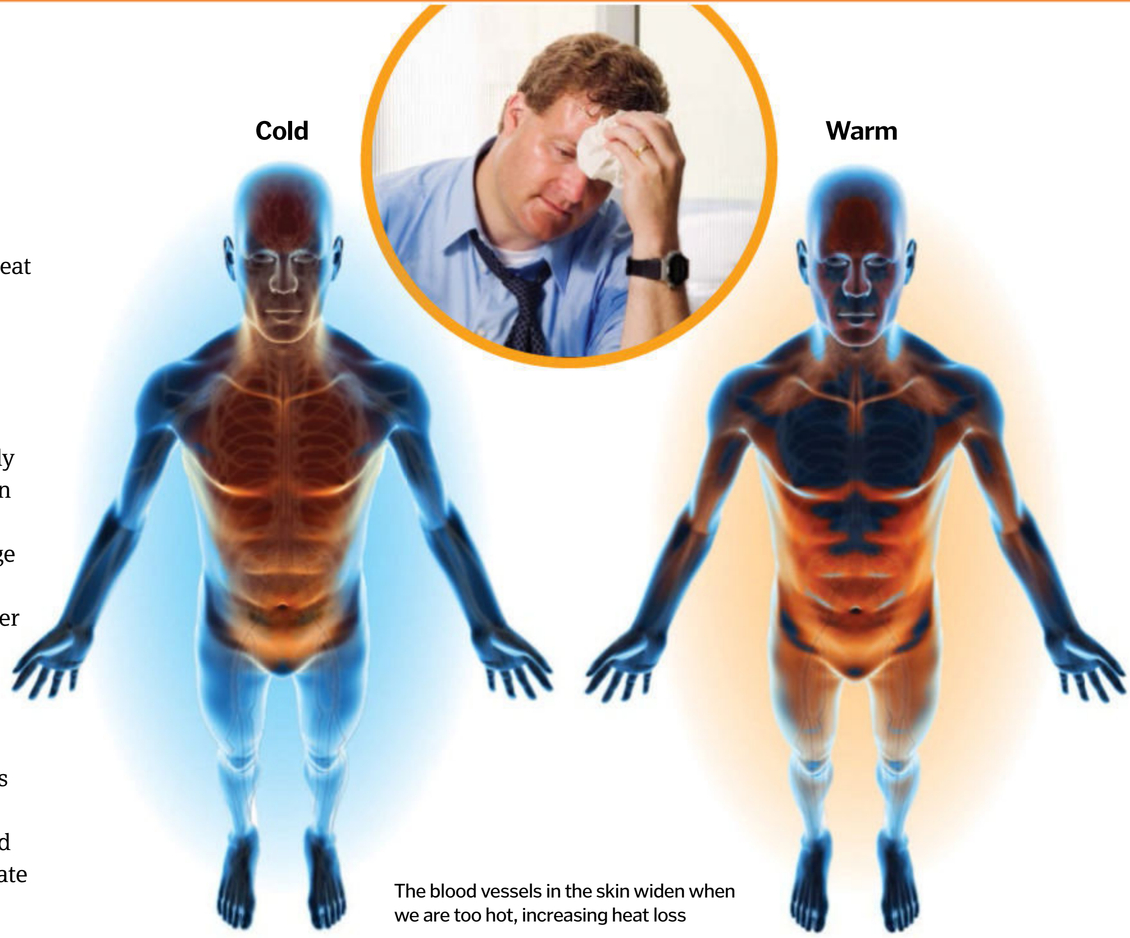
DID YOU KNOW? *Capsaicin in chillies activates heat-sensitive receptors, tricking the body into thinking that it is burning*

Temperature
(thermoception)

An internal thermostat keeps our body temperature at a constant 37°C (98.6°F)

It is crucial for our bodies to be able to detect heat and cold, firstly to ensure that our internal organs are kept at the right temperature to function properly, and secondly to prevent us being damaged by extremes. We are able to detect the temperature of our extremities by a series of nerves in the skin, while our core body temperature is monitored by a part of the brain known as the hypothalamus.

As warm-blooded animals, we generate huge amounts of heat as we burn sugars to release energy. This helps to keep us warm, but in order to maintain a constant temperature, adjustments need to be made continually to make up for changes in the environment or changes in our level of activity. For immediate changes in body temperature, the brain orders the body to shiver or sweat, and for more long-term regulation, the production of thyroid hormone is ramped up or down, altering the rate at which we burn sugars and generate heat.



The blood vessels in the skin widen when we are too hot, increasing heat loss

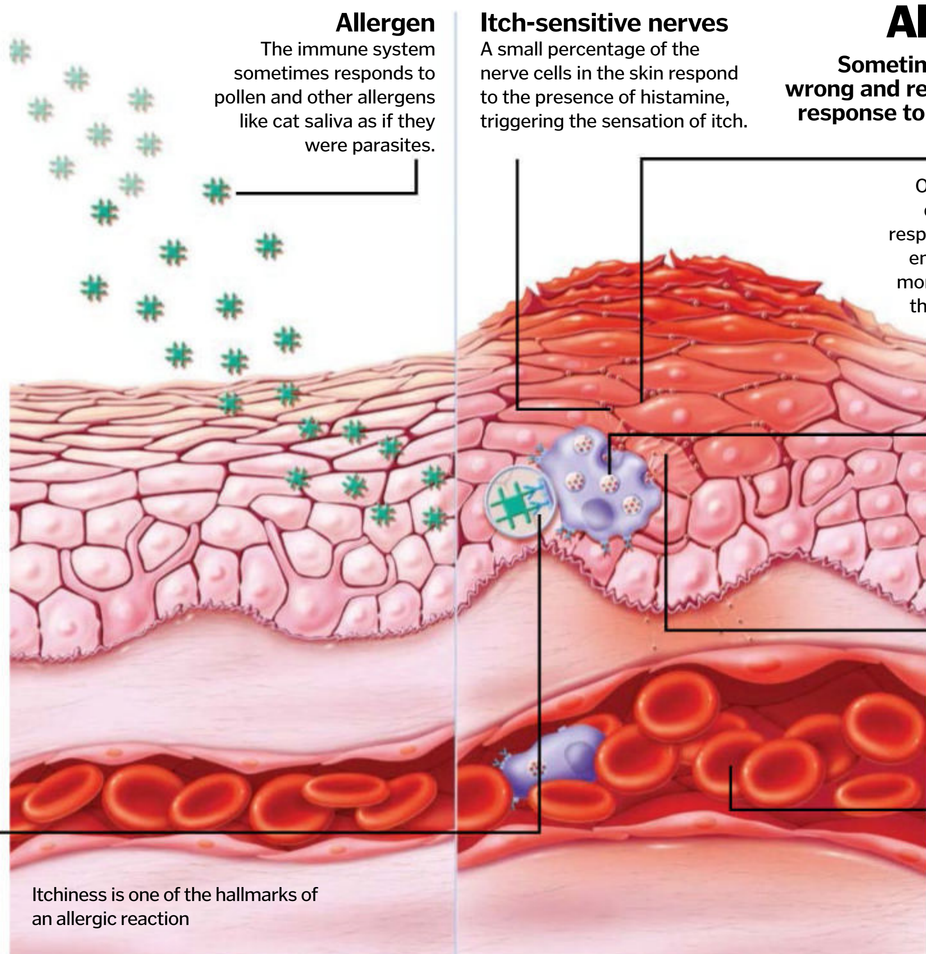
Itchiness

This unusual sensation is closely related to pain

Itchiness is the body's way of alerting us to parasites and irritants. It prompts a reflex scratch response, which scientists think is to draw our attention to that area of the body so any irritant can be eliminated. The exact science of itching is still unclear, but one of the most well studied culprits is a molecule known as histamine. Parasites like biting insects and worms often produce chemicals known as proteases, which help them to break through the barrier of the skin. These proteases trigger white blood cells to release histamine, which in turn activates our body's itch-sensitive nerve cells.

Allergic itch

Sometimes the body gets it wrong and releases histamine in response to harmless allergens

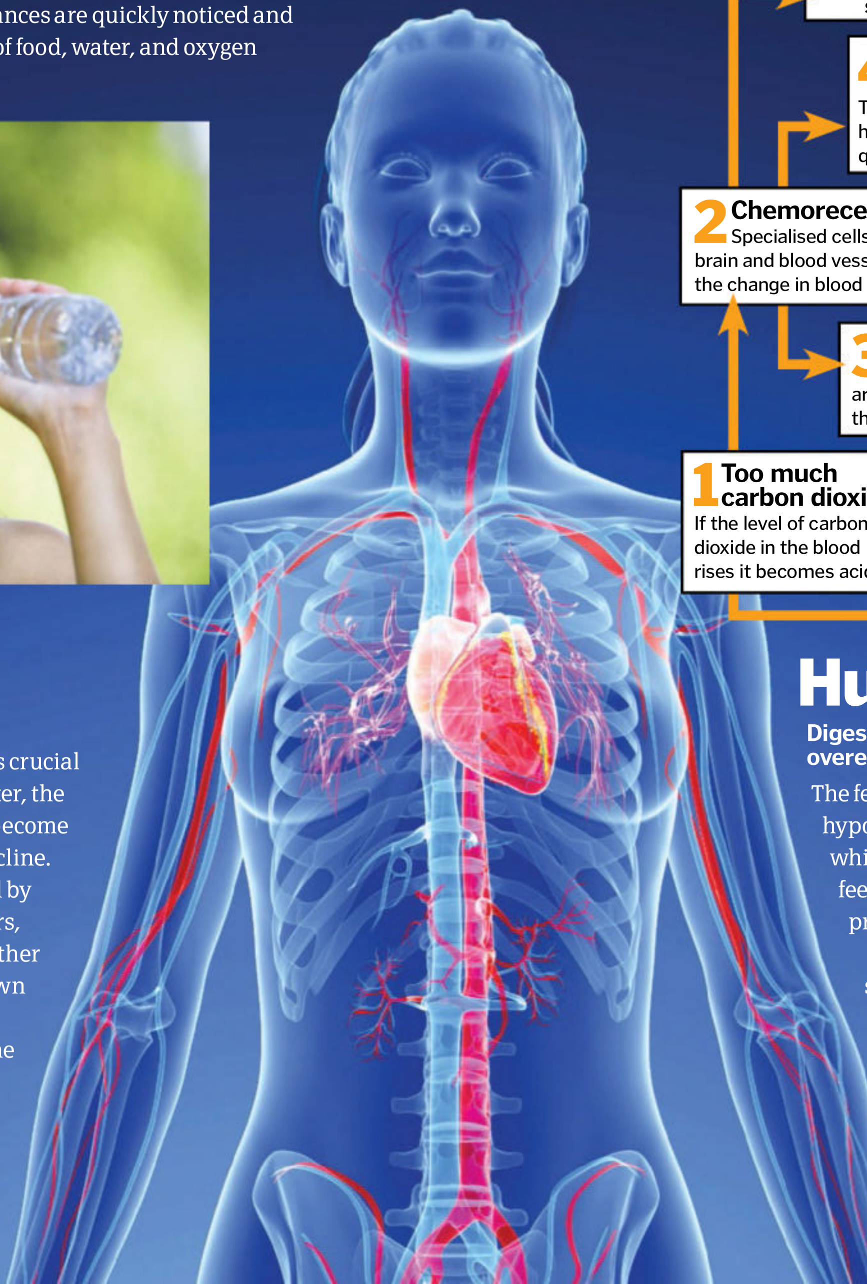


Itchiness is one of the hallmarks of an allergic reaction

Internal sensors

Specialist sensory cells inside the body supply the brain with information about vital systems

We are all familiar with the senses that allow us to interact with our external environment, but behind the scenes, we need to constantly keep track of events happening on the inside. If we didn't, our tissues would quickly run out of fuel and oxygen, and waste products would start to build up. The state of the body is constantly monitored by specialised sensory cells in the brain and organ systems, ensuring that any imbalances are quickly noticed and corrected, helping to ensure that the supply of food, water, and oxygen always meets the demand.



Thirst

Sensing the water level in our bodies prevents dangerous dehydration

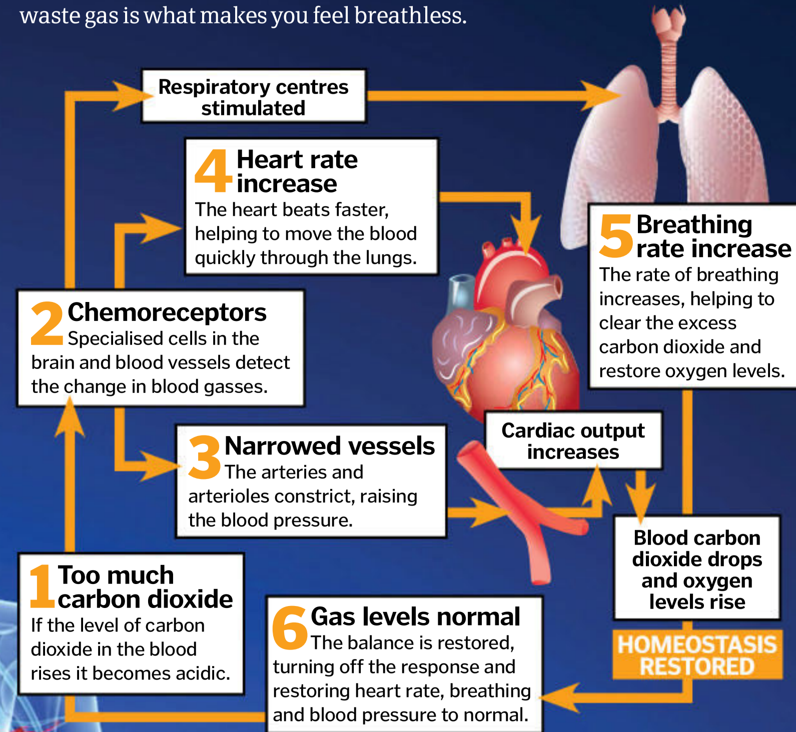
The ability to detect when we need to drink is crucial for survival. When we don't have enough water, the salts, sugars and proteins inside our bodies become more concentrated, and function starts to decline.

Minute changes in water level are detected by special cells in the brain called osmoreceptors, triggering the feeling of thirst. To prevent further water loss, the body releases a hormone known as vasopressin, which acts on the kidneys to stop water being excreted as urine. A hormone called angiotensin is also produced, making the blood vessels constrict and raising the blood pressure to compensate for the lack of water until more arrives.

Breathing

The ability to sense blood gases helps to keep oxygen and carbon dioxide levels normal

Breathing is controlled by the respiratory centres in the brain. Sensors in this area, along with sensors in the carotid artery and the aorta, detect the levels of gases in the blood and in the fluid that surrounds the brain. The carbon dioxide level is more important than the oxygen level, as a build up of this waste gas is what makes you feel breathless.

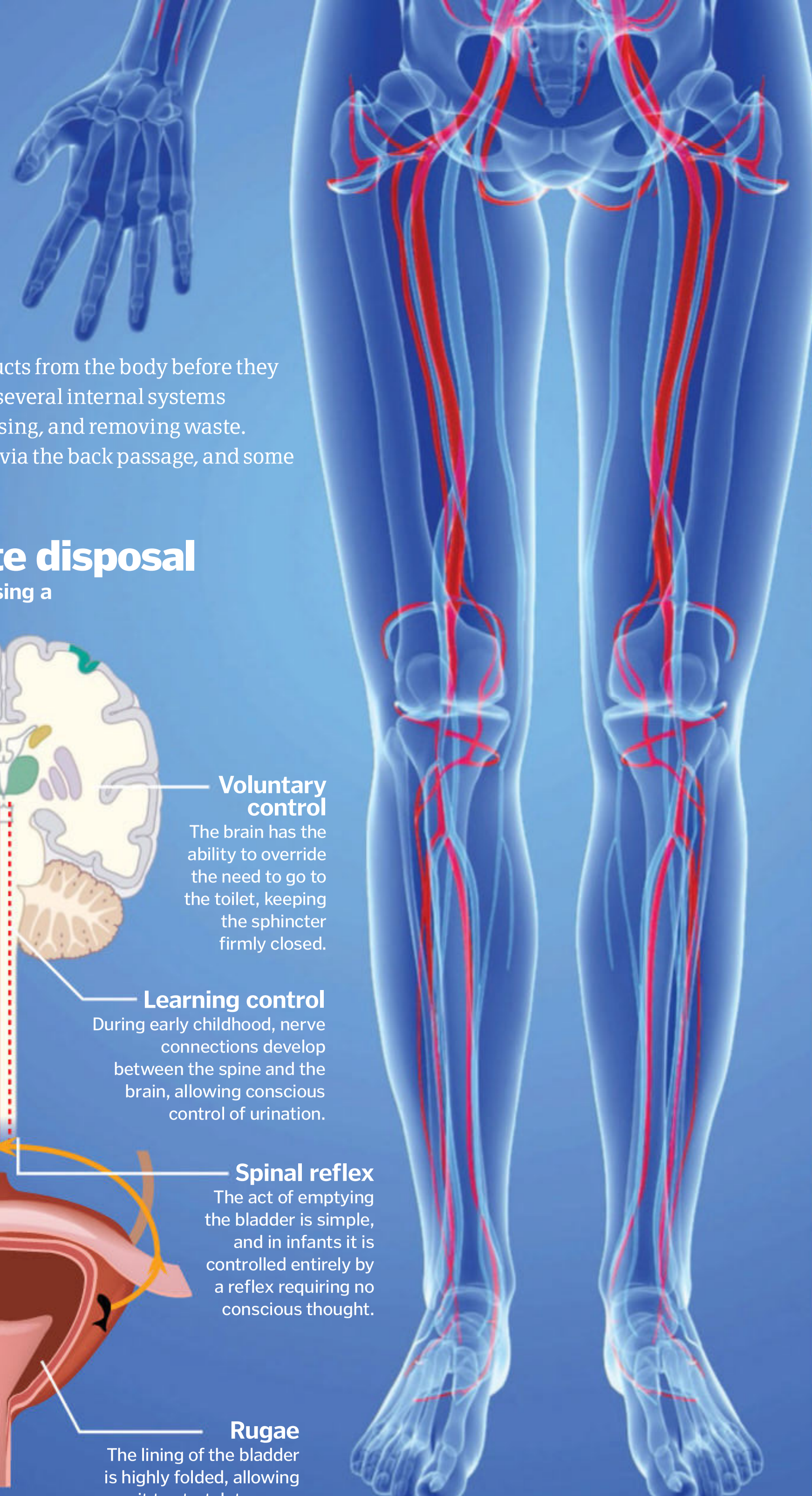


Hunger and fullness

Digestive sensors help to prevent us overeating, but they are easy to ignore

The feeling of hunger is controlled by a part of the brain called the hypothalamus. It produces two types of molecules: orexigens, which make you feel hungry; and anorexigens, which make you feel full. The hypothalamus decides which molecules to produce based on information sent by the digestive system.

When you haven't eaten for a while, the top part of the stomach starts to produce a molecule called ghrelin, signalling to the hypothalamus that you need to take in more food. After a meal, stretch receptors in your stomach help to signal that you are full, and when fat and protein start to enter the first part of the small intestine, a molecule called cholecystokinin (CCK) helps to switch the hungry feeling off.



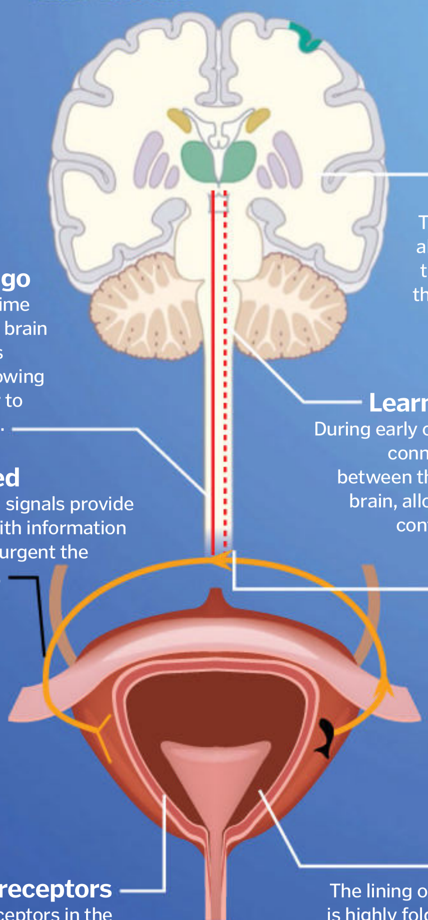
Excretion

Internal sensors help to time the elimination of waste products from the body

It is vital to remove waste products from the body before they start to build up, and there are several internal systems responsible for sensing, processing, and removing waste. Some leave via the lungs, some via the back passage, and some via the bladder.

Control of waste disposal

Bladder emptying is timed using a specialised sense of touch



Fat produces a hormone called leptin, which helps the brain keep track of how much energy is stored

Animal senses

Magnetoreception

This incredible sense allows animals to detect Earth's magnetic field, and is shared by a diverse array of species, from honeybees to sea turtles. Birds may actually be able to see Earth's magnetic field lines by detecting the subtle changes that they make to the light, helping them to navigate in unfamiliar territory.

Electroreception

Muscle movements are powered by electrical impulses, and in water, dissolved ions can transmit the tiny currents. Many aquatic species are able to detect these subtle pulses, alerting them to danger or guiding them to their prey. Sharks, skates and rays have jelly-filled pores known as ampullae of Lorenzini, capable of detecting the slight differences in voltage as a fish swims past.

Heat vision

This specialised sense is used by pit vipers and some other snakes to detect the heat signature given off by their prey. Tiny pits on either side of the snake's head contain thousands of nerve endings that pick up infrared radiation, detecting changes in temperature of just fractions of a degree.

CURIOUS QUESTIONS

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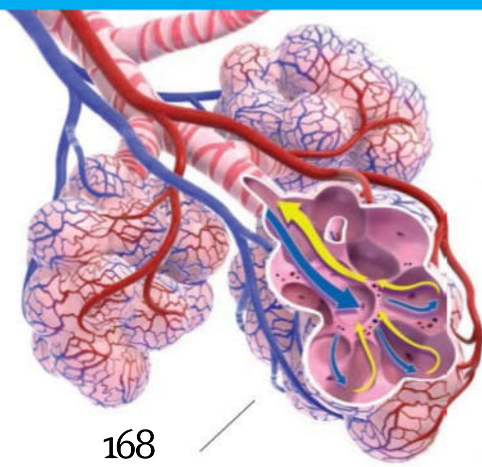
What makes your nose run?



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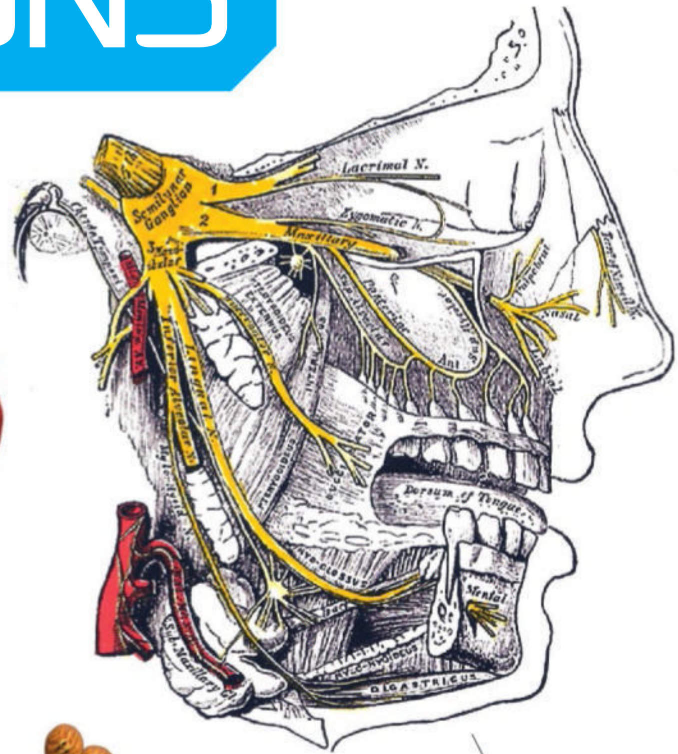
What do alveoli do?



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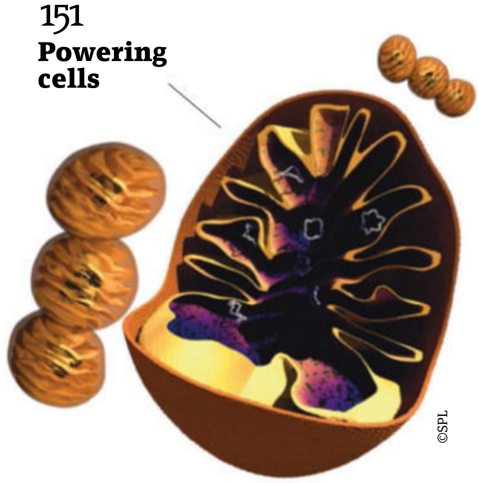
Brain freeze explained



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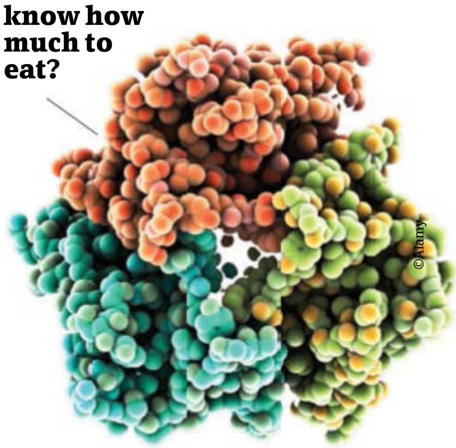
Powering cells



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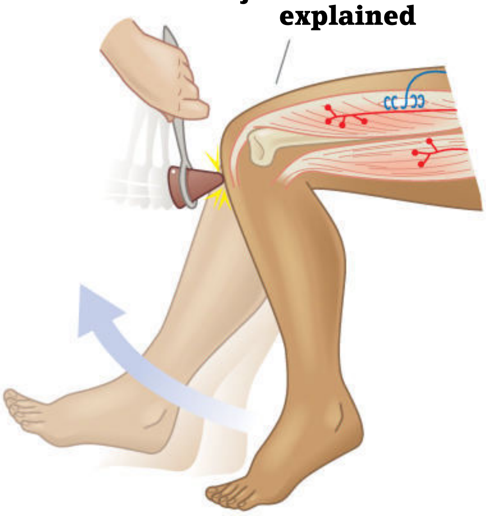
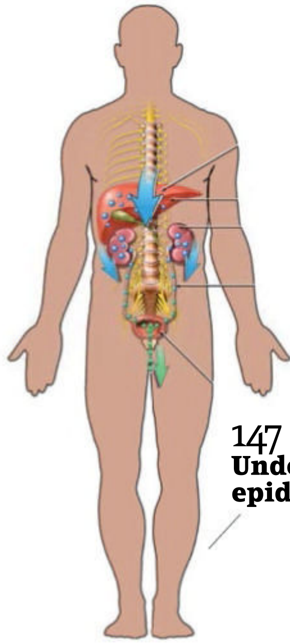
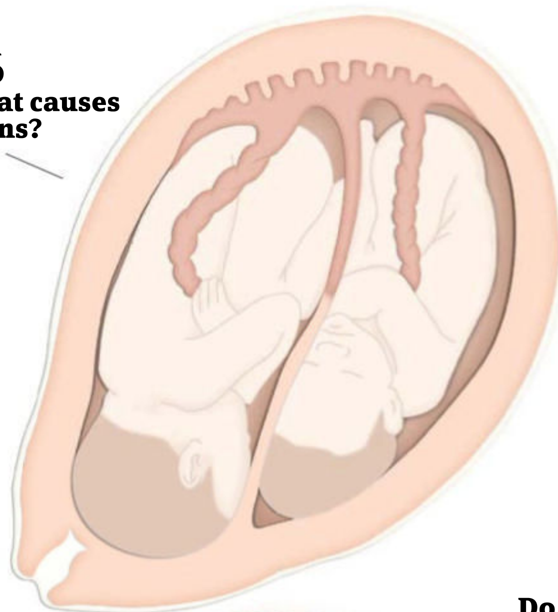
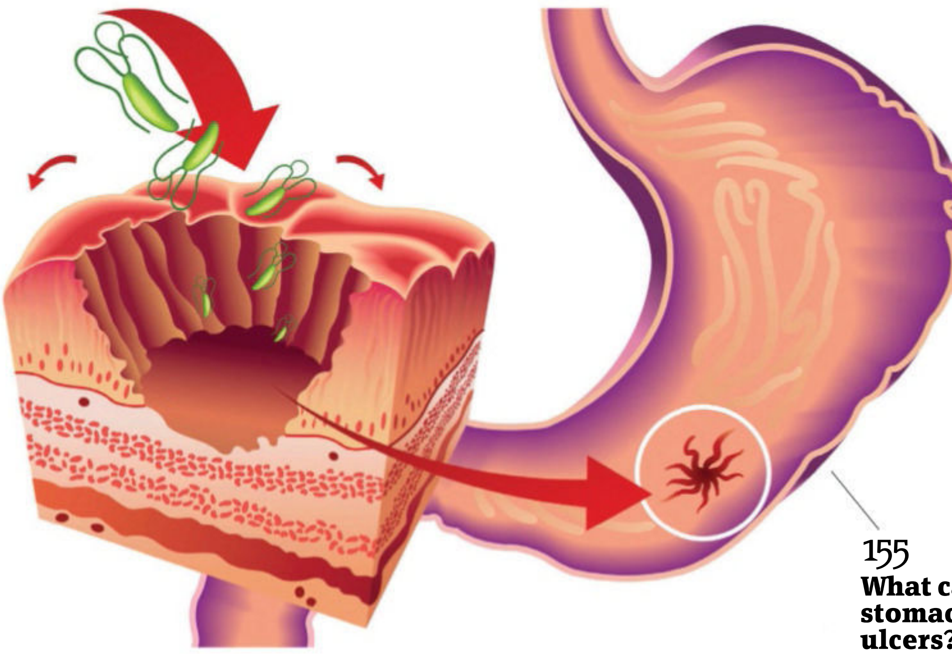
How do we know how much to eat?









Left or right brained?

Actually, you're neither. Discover the truth behind the way we think

It's true that the different sides of the brain perform different tasks, but do these anatomical asymmetries really define our personalities? Some psychologists argue that creative, artistic individuals have a more developed right hemisphere, while analytical, logical people rely more heavily on the left side of the brain, but so far, the evidence for this two-sided split has been lacking.

In a study published in the journal PLOS ONE, a team at the University of Utah attempted to answer the question. They divided the brain up into 7,000 regions and analysed the fMRI scans of over 1,000 people, in order to determine whether the networks on one side of the brain were stronger than the networks on the other.

Despite the popularity of the left versus right brain myth, the team found no difference in the strength of the networks in each hemisphere, or in the amount we use either side of our brains. Instead, they showed that the brain is more like a network of computers. Local nerves can communicate more efficiently than distant ones, so instead of sending every signal across from one hemisphere of the brain to the other, neurones that need to be in constant communication tend to develop into organised local hubs, each responsible for a different set of functions.

Hubs with related functions cluster together, preferentially developing on the same side of the brain, and allowing the nerves to communicate rapidly on a local scale. One example is language processing – in most people, the regions of the brain involved in speech, communication and verbal reasoning are all located on the left-hand side.

Some areas of the brain are less symmetrical than others, but both hemispheres are used relatively equally. There is nothing to say you can't be a brilliant scientist and a great artist.

Examining the human brain

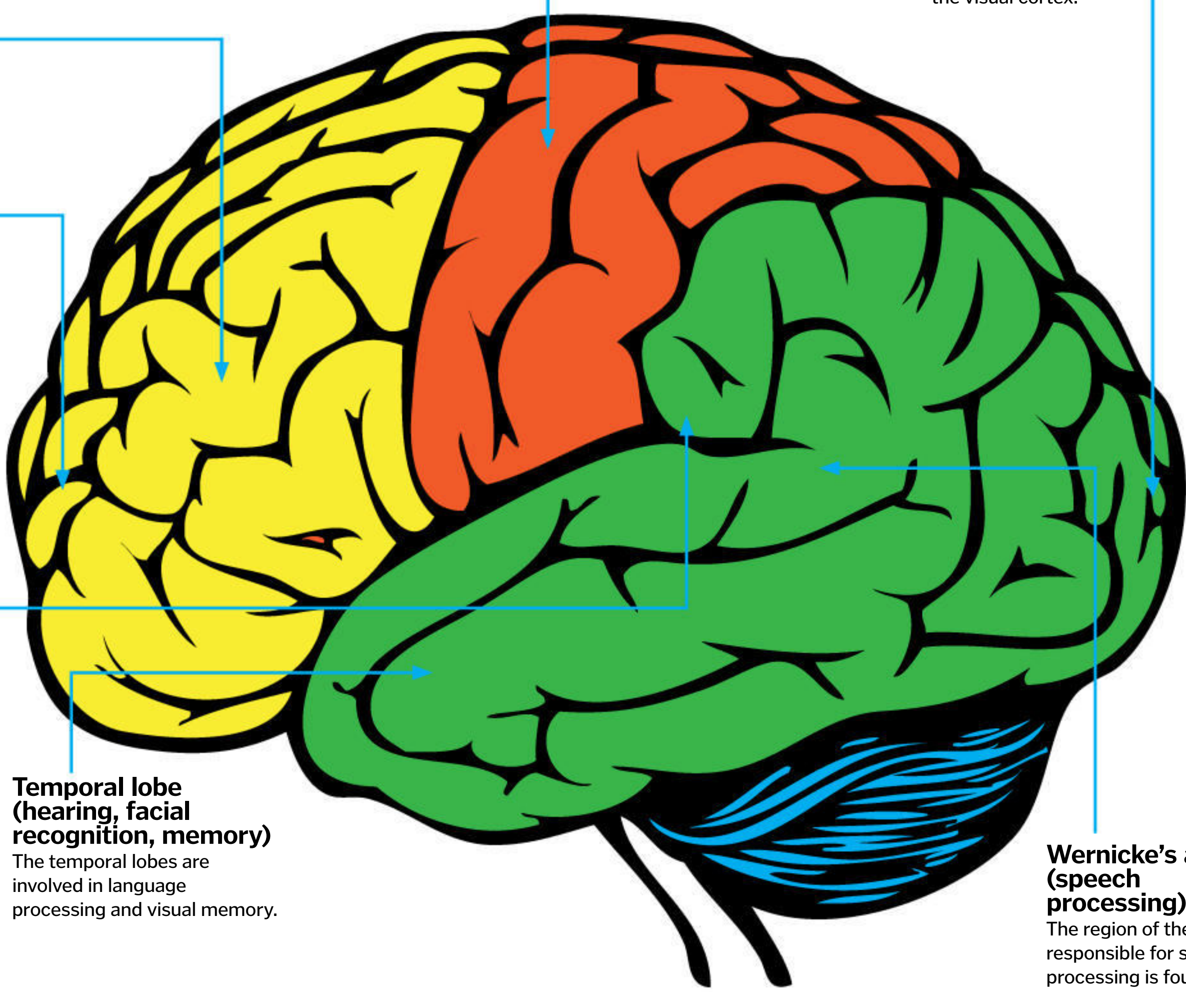
What do the different parts of the brain actually do?

Parietal lobe (pressure, taste)
The parietal lobes handle sensory information and are involved in spatial awareness and navigation.

Occipital lobe (vision)
Incoming information from the eyes is processed at the back of the brain in the visual cortex.

Broca's area (speech)
Broca's area is responsible for the ability to speak and is almost always found on the left side of the brain.

Frontal lobe (planning, problem solving)
At the front of each hemisphere is a frontal lobe, the left side is more heavily involved in speech and verbal reasoning, while the right side handles attention.

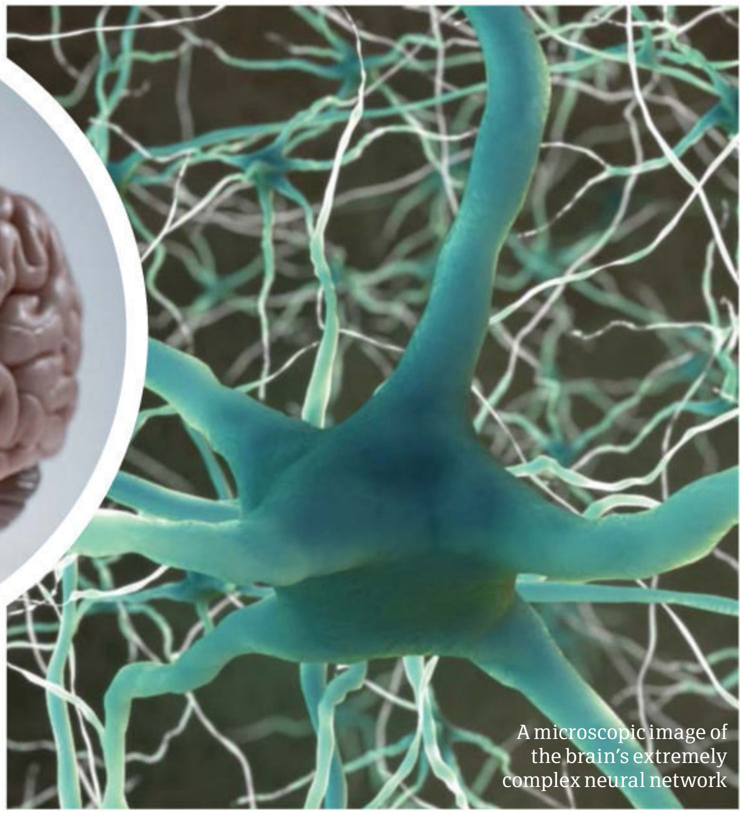


Auditory cortex (hearing)
The auditory cortex is responsible for processing information from the ears and can be found on both sides of the brain, in the temporal lobes.

Temporal lobe (hearing, facial recognition, memory)
The temporal lobes are involved in language processing and visual memory.

Wernicke's area (speech processing)
The region of the brain responsible for speech processing is found on the left-hand side.

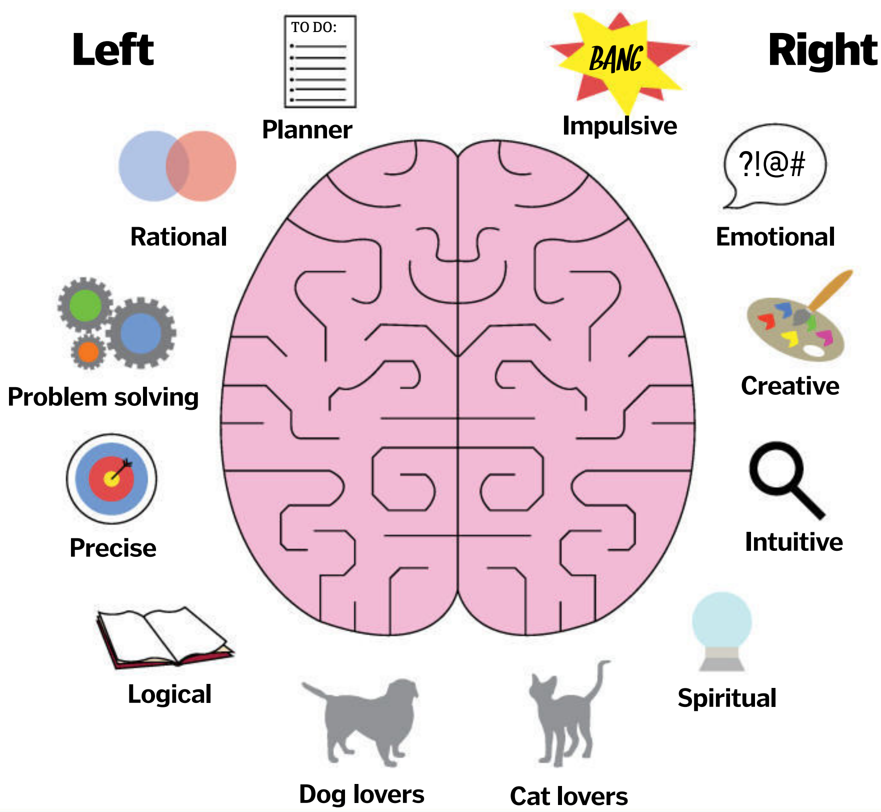
It took 82,944 computer processors 40 minutes to simulate just one second of human brain activity, it's that powerful



A microscopic image of the brain's extremely complex neural network

Myth-taken identity

The left vs right brain personality myth is actually based on Nobel Prize-winning science. In the 1940s, a radical treatment for epilepsy was trialled; doctors severed the corpus callosum of a small number of patients, effectively splitting their brains in two. If a patient was shown an object in their right field of view, they had no difficulty naming it, but if they were shown the same object from the left, they couldn't describe it. Speech and language are processed on the left side of the brain, but the information from the left eye is processed on the right. The patients were unable to say what they saw, but they could draw it. Psychologists wondered whether the differences between the two hemispheres could create two distinctive personality types, left-brained and right-brained.



Give your brain a fun workout

1 Boost your memory

Look at this list of items for one minute, then cover the page and see how many you can remember:

Coin	Telephone	Grape
Duck	Potato	Pillowcase
Key	Teacup	Bicycle
Pencil	Match	Table

Difficult? Try again, but this time, make up a story in your head, linking the objects together in a narrative.

...You get the idea. Make it as silly as you like; strange things are much more memorable than the mundane.

2 Slow brain ageing

Learning a new language is one of the best ways to keep your brain active. Here are four new ways to say hello:

- Polish: Cześć! (che-sh-ch)
- Russian: Zdravstvuj (zdrah-stvooy)
- Arabic: Marhaba (mar-ha-ba)
- Swahili: Hujambo (hud-yambo)

What is 'brain freeze'?

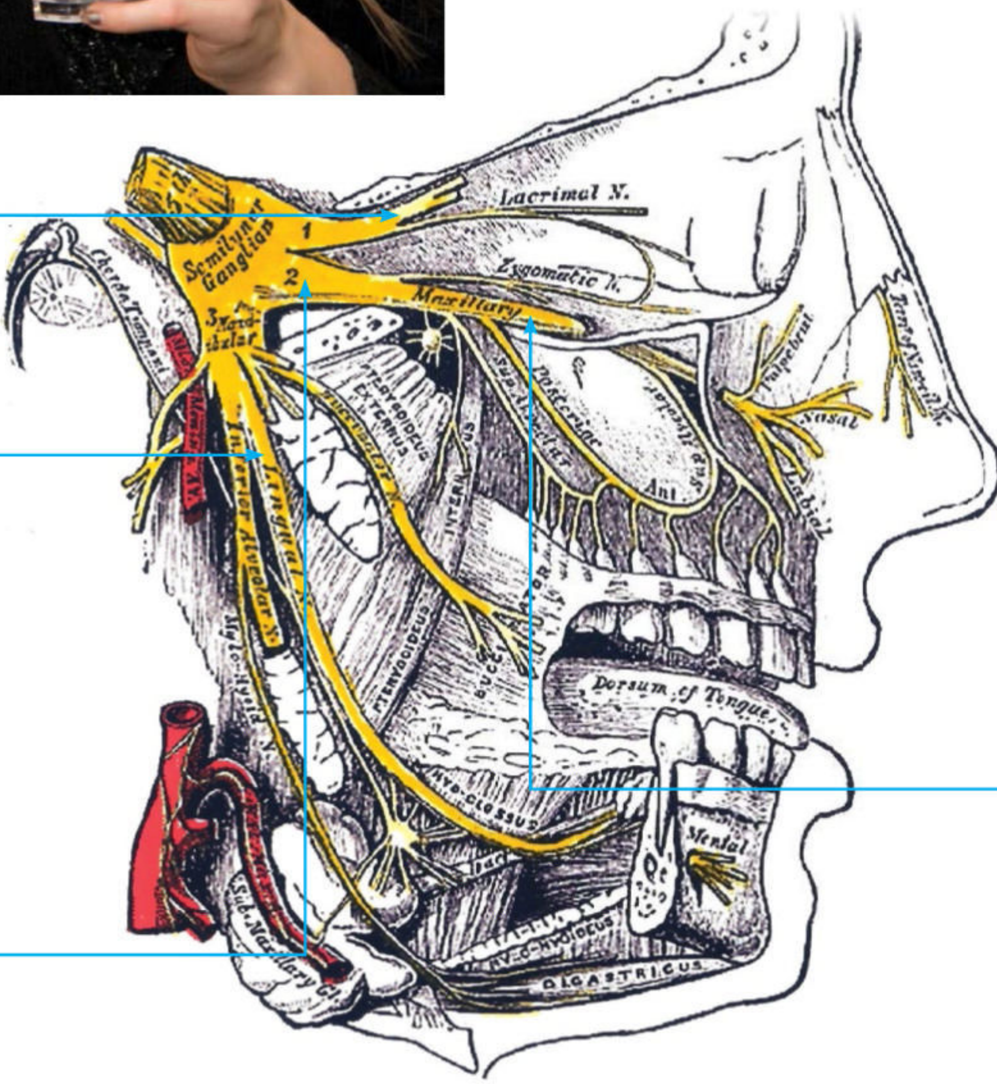
That intense pain you sometimes get when you eat ice cream too fast is technically called sphenopalatine ganglioneuralgia, and it's related to migraine headaches

The pain of a brain freeze, also know as an ice cream headache, comes from your body's natural reaction to cold. When your body senses cold, it wants to conserve heat. One of the steps it takes to accomplish this is constricting the blood vessels near your skin. With less blood flowing near your skin, less heat is carried away from your core, keeping you nice and warm.

The same thing happens when something really cold hits the back of your mouth. The blood vessels in your palate constrict rapidly. When the cold goes away (because you swallowed the ice cream or cold beverage), they rapidly dilate back to their standard, normal state.

This is harmless, but a major facial nerve called the trigeminal lies close to your palate and this nerve interprets the constriction/dilation process as pain. The location of the trigeminal nerve can cause the pain to seem like its coming from your forehead. Doctors believe this same misinterpretation of blood vessel constriction/dilation is the cause of the intense pain of a migraine headache.

> "A major facial nerve called the trigeminal lies close to your palate"



The Ophthalmic branch carries sensory messages from the eyeball, tear gland, upper nose, upper eyelid, forehead, and scalp.

The Mandibular branch carries sensory signals from the skin, teeth and gums of the lower jaw, as well as tongue, chin, lower lip and skin of the temporal region.

The trigeminal facial nerve is positioned very close to the palate. This nerve interprets palate blood vessel constriction and dilation as pain.

The Maxillary branch carries sensory messages from the skin, gums and teeth of the upper jaw, cheek, upper lip, lower nose and lower eyelid.

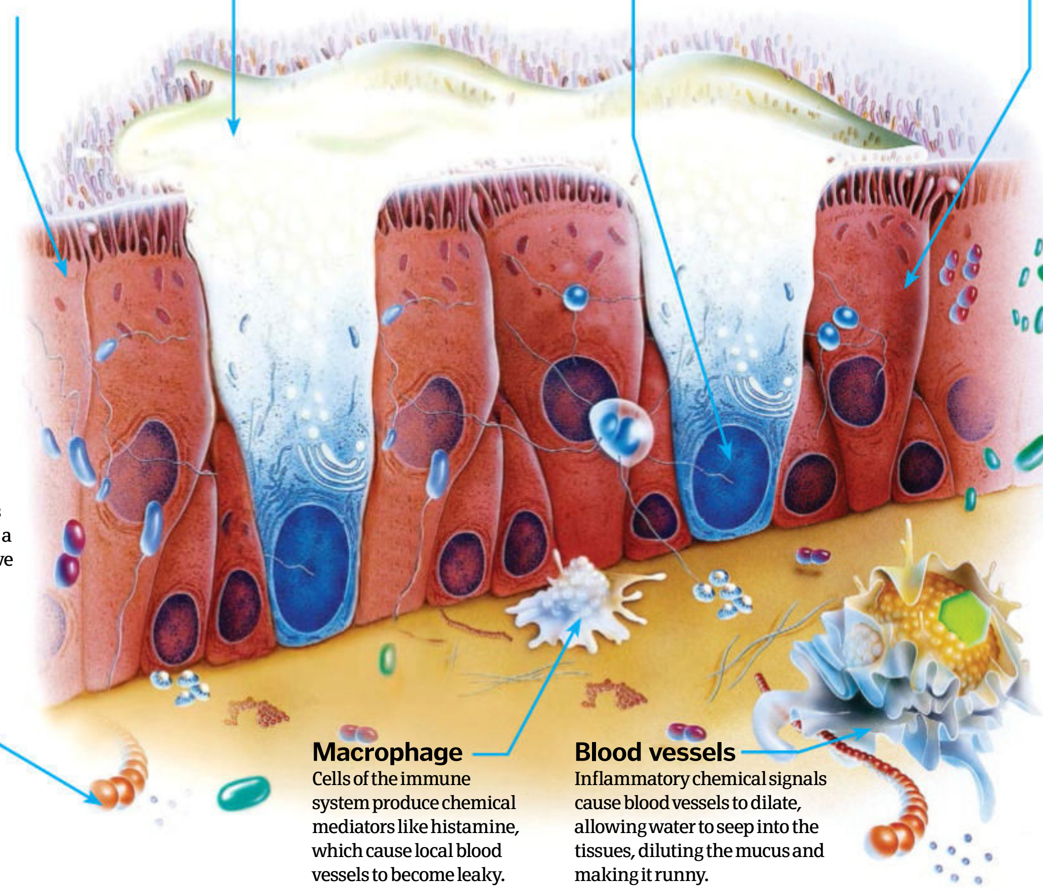
What makes your nose run?

Discover what is going on inside a blocked nose and why it gets runny when we're ill

It surprises many people but the main culprit responsible for a blocked and runny nose is typically not excess mucus but swelling and inflammation.

If the nose becomes infected, or an allergic reaction is triggered, the immune system produces large quantities of chemical messengers that cause the local blood vessels in the lining of the nose to dilate. This enables more white blood cells to enter the area, helping to combat the infection, but it also causes the blood vessels to become leaky, allowing fluid to build up in the tissues.

Decongestant medicine contains a chemical that's similar to adrenaline, which causes the blood vessels to constrict, stopping them from leaking.



How is a person brought out of a coma?

When we talk about 'bringing someone out of a coma', we are referencing medically induced comas. A patient with a traumatic brain injury is deliberately put into a deep state of unconsciousness to reduce swelling and allow the brain to rest. When the brain is injured, it becomes inflamed. The swelling damages the brain because it is squashed inside the skull.

Doctors induce the coma using a controlled dose of drugs. To bring the person out of the coma, they simply stop the treatment. Bringing the patient out of the coma doesn't wake them immediately. They gradually regain consciousness over days, weeks or longer. Some people make a full recovery, others need rehabilitation or lifetime care and others may remain unaware of their surroundings.

"Rapid altitude changes make the 'pop' much more noticeable"

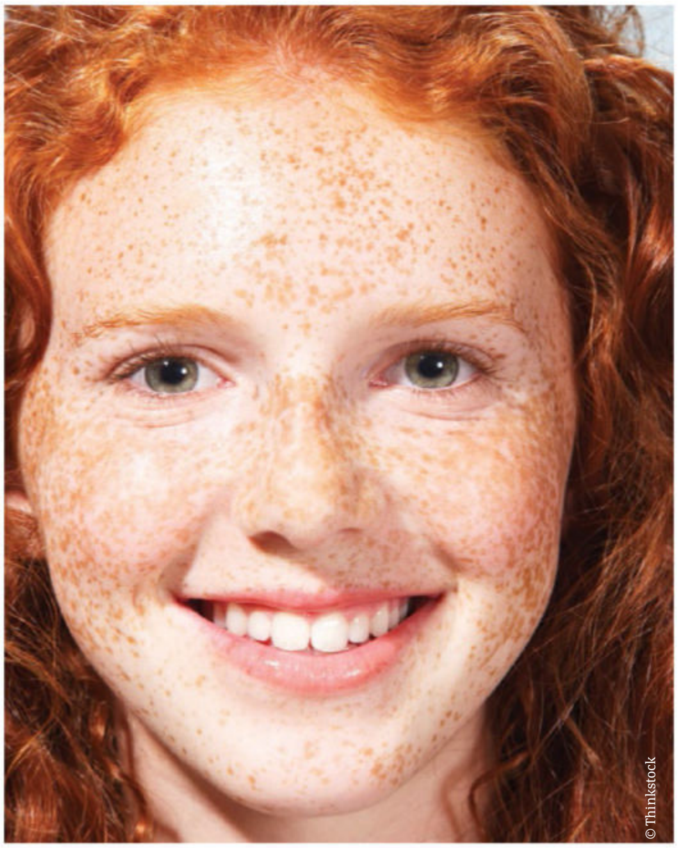
Why do our ears 'pop' on planes?

The eardrum is a thin membrane that helps to transmit sound. Air pressure is exerted on both sides of the eardrum; with the surrounding atmospheric pressure pushing it inwards while air being delivered via a tube between the back of your nose and the eardrum pushes it outwards. This tube is called the Eustachian tube, when you swallow ot opens and a small bubble of air is able to move causing a 'pop'.

Rapid altitude changes in planes make the 'pop' much more noticeable due to bigger differences in pressure. Air pressure decreases as a plane ascends; hence air must exit the Eustachian tubes to equalise these pressures, again causing a 'pop'. Conversely, as a plane descends, the air pressure starts to increase; therefore the Eustachian tubes must open to allow through more air in order to equalise the pressure again, causing another 'pop'.

What are freckles?

Freckles are clusters of the pigment melanin. It is produced by melanocytes deep in the skin, with greater concentrations giving rise to darker skin tones, and hence, ethnicity. Melanin protects the skin against harmful ultraviolet sunlight, but is also found in other locations around the body,. Freckles are mostly genetically inherited, but not always. They become more prominent during sunlight exposure, as the melanocytes are triggered to increase production of melanin, leading to a darker complexion. People with freckles generally have pale skin tones, and if they stay in the Sun for too long they can damage their skin cells, leading to skin cancers like melanoma.



Why does hot honey and lemon help your throat when it's sore?

Honey and lemon can be drank warm as a comfort remedy, and is a popular drink with many who are feeling unwell. The idea is that honey coats the throat and therefore any inflamed areas will be 'protected' by a layer of honey, while at the same time soothing painful areas. This means it will be less painful when these areas come into contact with other surfaces when you eat or swallow. Lemon also helps to settle the stomach too, as it contains acid, which can be particularly helpful when experiencing an upset stomach from the effects of a cold or other digestion-related illness.

What is an epidural?

The science behind blocking pain explained

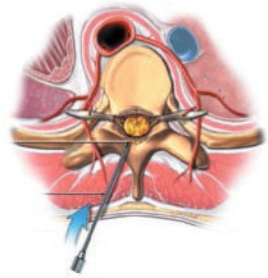
An epidural (meaning 'above the dura') is a form of local anaesthetic used to completely block pain while a patient remains conscious. It involves the careful insertion of a fine needle deep into an area of the spine between two vertebrae of the lower back.

This cavity is called the epidural space. Anaesthetic medication is injected into this cavity to relieve pain or numb an area of the body by reducing sensation and blocking the nerve roots that transmit signals to the brain.

The resulting anaesthetic medication causes a warm feeling and numbness leading to the area being fully anaesthetised after about 20 minutes. Depending on the length of the procedure, a top-up may be required.

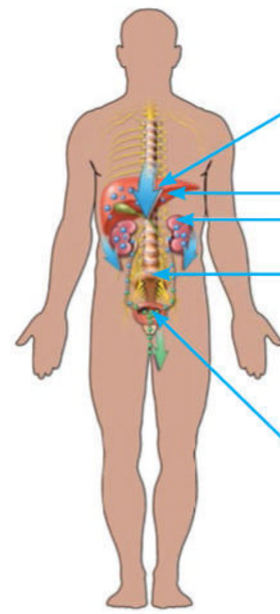
This form of pain relief has been used widely for many years, particularly post-surgery and during childbirth.

1. Epidural space
The outer part of the spinal canal, this cavity is typically about 7mm (0.8in) wide in adults.

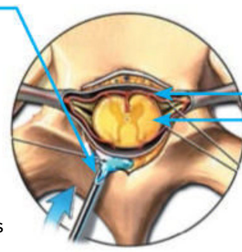


2. Epidural needle
After sterilising the area, a needle is inserted into the interspinous ligament until there is no more resistance to the injection of air or saline solution.

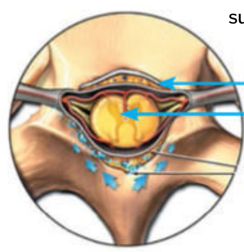
6. Processing
Anaesthetic in the blood is filtered out by theliver and kidneys, then leaves the body in urine. The effects usually wear off a couple of hours after the initial injection.



3. Anaesthetic
Through a fine catheter in the needle, anaesthetic is carefully introduced to the space surrounding the spinal dura.



4. Absorption
Over about 20 minutes the anaesthetic medication is broken down and absorbed into the local fatty tissues.



5. Radicular arteries
The anterior and posterior radicular arteries run with the ventral and dorsal nerve roots, respectively, which are blocked by the drug.

What is a memory?

Memory is the brain's ability to recall information from the past and it generally falls into three categories – sensory, short-term and long-term.

Look at this page then close your eyes and try to remember what it looks like. Your ability to recall what this page looks like is an example of your sensory memory. Depending on whether or not this page is important to you will be the determining factor in how likely it is that it will get passed on to your short-term memory.

Can you remember the last thing you did before reading this? That is your short-term memory and is a bit like a temporary storage facility where the less-important stuff can decay, whereas the more important stuff can end up in the long-term memory.

Our senses are constantly being bombarded with information. Electrical and chemical signals travel from our eyes, ears, nose, touch and taste receptors and the brain then makes sense of these signals. When we remember something, our brain refires the same neural pathways along which the original information travelled. You are almost reliving the experience by remembering it.

How does toothpaste for sensitive teeth work?

Imagine just one of your teeth. It has two primary sections: the crown located above the gum line and the root below it. The crown comprises the following layers from top to bottom: enamel, dentine and the pulp gum. Nerves branch from the root to the pulp gum. The dentine runs to the root and contains a large number of tubules or microscopic pores, which run from the outside of the tooth right to the nerve in the pulp gum.

People with sensitive teeth experience pain when their teeth are exposed to something hot, cold or when pressure is applied. Their layer of enamel may be thinner and they may have a receded gum line exposing more dentine. Therefore, the enamel and gums offer less protection and, as such, this is what makes their teeth sensitive.

Sensitive toothpaste works by either numbing tooth sensitivity, or by blocking the tubules in the dentine. Those that numb usually contain potassium nitrate, which calms the nerve of the tooth. The toothpastes that block the tubules in the dentine usually contain a chemical called strontium chloride. Repeated use builds up a strong barrier by plugging the tubules more and more.

Why and how do we blush?

Blushing occurs when an excess of blood flows into the small blood vessels just under the surface of the skin. Facial skin has more capillary loops and vessels, and vessels are nearer the surface so blushing is most visible on the cheeks, but may be seen across the whole face. The small muscles in the vessels are controlled by the nervous system.

Blushing can be affected by factors such as heat, illness, medicines, alcohol, spicy foods, allergic reactions and emotions. If you feel guilty, angry, excited or embarrassed, you will involuntarily release adrenaline, which sends the automatic nervous system into overdrive. Your breathing will increase, heart rate quicken, pupils dilate, blood will be redirected from your digestive system to your muscles, and you blush because your blood vessels dilate to improve oxygen flow around the body; this is all to prepare you for a fight or flight situation. The psychology of blushing remains elusive; some scientists even believe we have evolved to display our emotions, to act as a public apology.

"Blushing can be affected by heat, illness, medicines and spicy foods"

What makes caffeine so addictive?

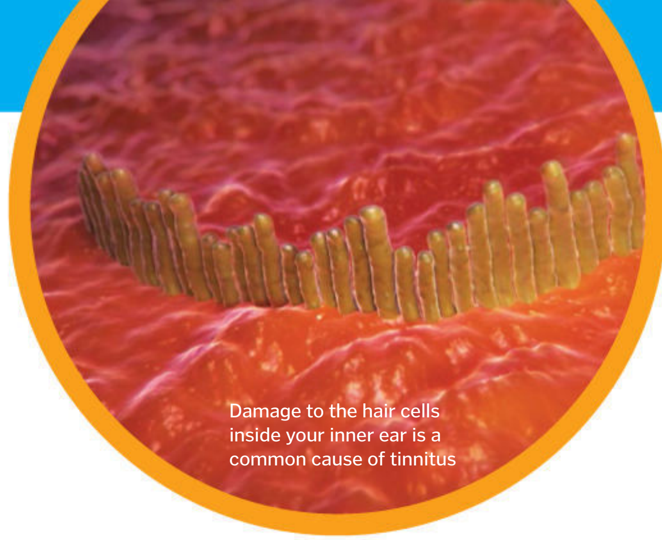
When we are awake the naturally occurring brain chemical adenosine is drawn to fast moving receptors in the brain. As adenosine attaches to the receptors it slows them down, which causes us to feel sleepy.

The receptor cells confuse caffeine for adenosine cells and as such willingly bond to it. The action doesn't slow down the receptor's movement as adenosine would and as the space is usurped they are unable to sense adenosine so the cells speed up, increasing neuron firing in the brain. The pituary gland interprets this as a fight or flight scenario so releases hormones to alert the adrenal glands to produce adrenaline. This results in dilated pupils, a racing heart and an increase in blood pressure. The liver also releases sugar into the bloodstream for an instant energy boost.

What makes us faint?

Fainting, or 'syncope', is a temporary loss of consciousness due to a lack of oxygen to the brain. It is preceded by dizziness, nausea, sweating and blurred vision.

The most common cause is overstimulation of the body's vagus nerve. Possible triggers of this include intense stress and pain, standing up for long periods or exposure to something unpleasant. Severe coughing, exercise and even urinating can sometimes produce a similar response. Overstimulation of the vagus nerve results in dilation of the body's blood vessels and a reduction of the heart rate. These two changes together mean that the body struggles to pump blood up to the brain against gravity. A lack of blood to the brain means there is not enough oxygen for it to function properly and fainting occurs.


Damage to the hair cells inside your inner ear is a common cause of tinnitus

What is tinnitus?

Find out why your ears ring after a concert

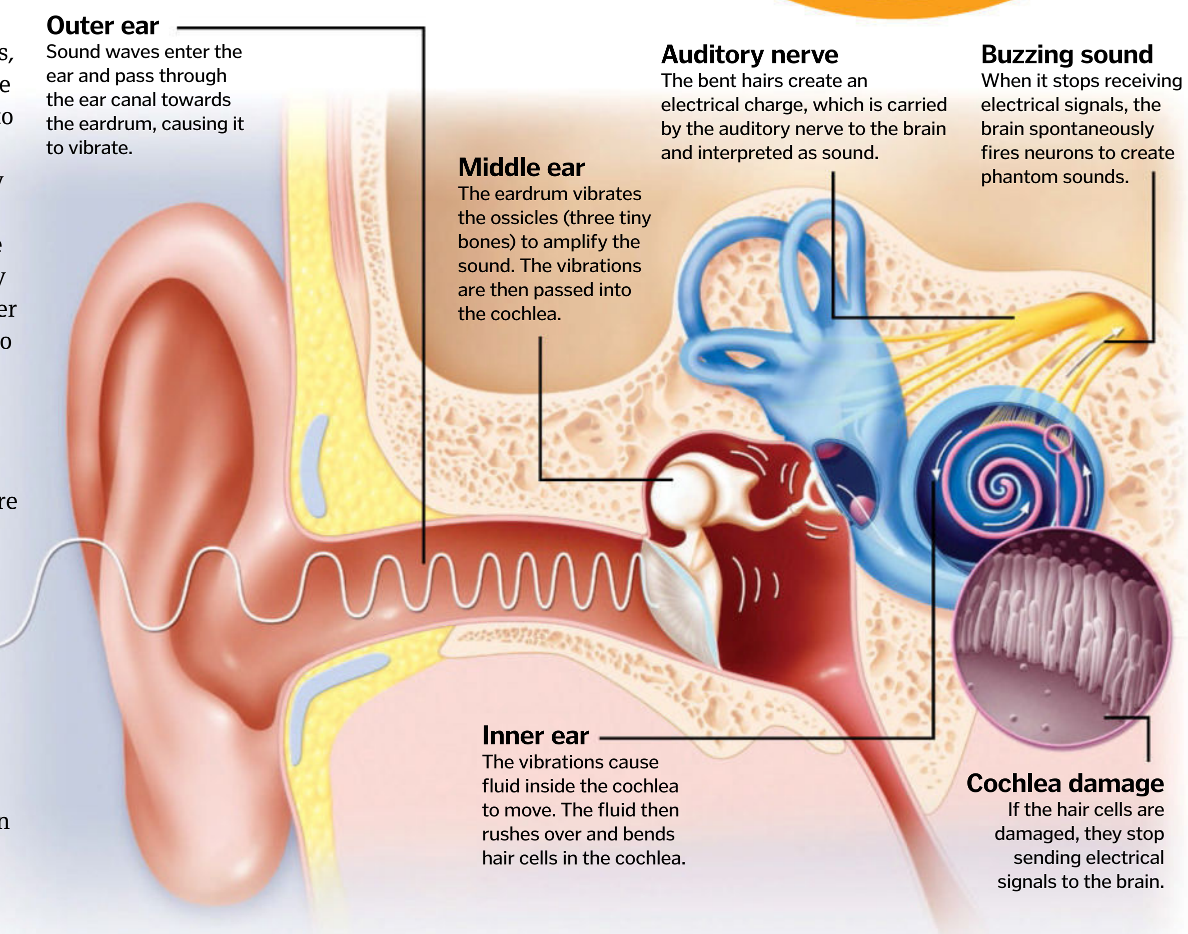
Tinnitus is a sound you can hear that isn't caused by an outside source and often manifests as a buzzing, ringing, whistling or humming noise. One of the most common causes of tinnitus is exposure to loud noises, which is why you often experience a ringing in your ears after going to a music concert.

The loud music can temporarily damage the hair cells inside your ear and cause your brain to create phantom sounds that aren't really there. They usually disappear after a while, but prolonged exposure to loud noises can damage the hair cells permanently, resulting in a buzzing that never goes away. There is currently no cure for this type of tinnitus as the hair cells are unable to repair or replace themselves. Therefore, if you're regularly exposed to loud noises, it's important to wear earplugs to protect your delicate ears.

Loud noises are not the only cause of tinnitus, though. Other factors including a build-up of earwax, an ear infection, certain medications, a head injury or even high blood pressure, can also affect the inner workings of your ear and cause phantom sounds.

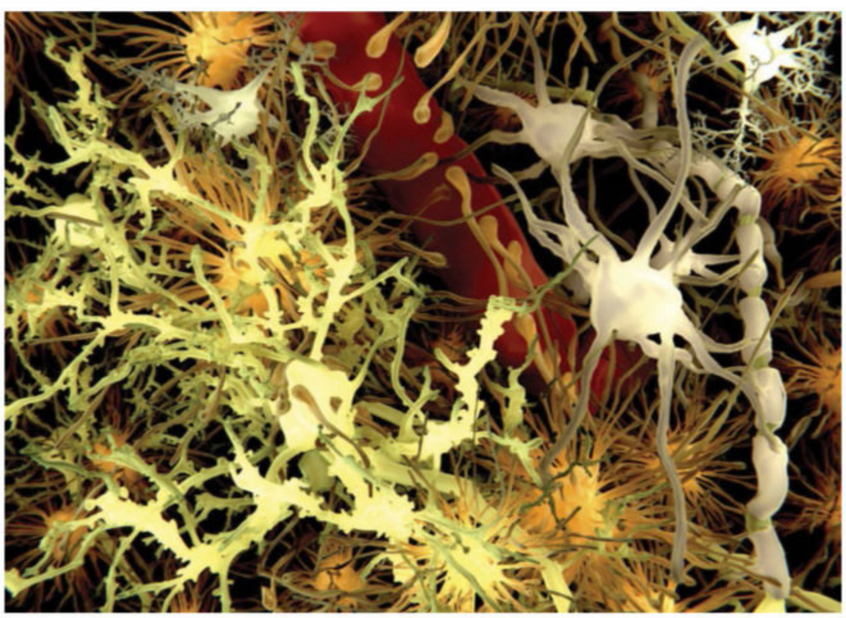
What's that buzzing?

How your ears and brain interpret real and phantom sounds



When does your brain stop growing?

By the time a child is two years old, their brain is around 80 per cent of its adult size, but it continues to grow right up until they reach their mid-20s. However, most of this growth is not driven by the nerve cells themselves. Babies are born with almost all of the nerve cells that their brains will ever need, and the increase in size is mostly down to an increase in the number of support cells, also known as glial cells. These fill the gaps between nerve cells, and play a vital role in cleaning up debris, providing nutrition, and physically supporting and insulating the neurons in the brain. As children develop, new connections are also made between neighbouring nerve cells, contributing to brain growth.


Nerve cells in the brain are supported by glial cells

How 72-hour deodorants work

Discover the chemistry that helps us combat body odour for up to days at a time

Deodorants prevent the odour associated with sweating, either by masking it, or by killing the bacteria responsible. To make the effects last longer, the active ingredients are sometimes encased within microcapsules. As the capsules take up water from sweat they burst, releasing deodorising chemicals. By including capsules of a variety of sizes, each requiring a different amount of water to burst, the duration can be extended.

Most deodorants also contain antiperspirants, which prevent sweating from occurring at all. These are usually aluminium-based compounds. The aluminium is taken up by the cells that line the openings of the ducts that carry sweat to the surface of the skin.

As the aluminium moves into the cells, it takes water with it, causing the cells to swell and closing off the ducts. Depending on the type of aluminium compound used, the effect will last for different lengths of time.

Antiperspirants cause cells to swell and the ducts to close up, preventing sweating altogether

Modern fillings

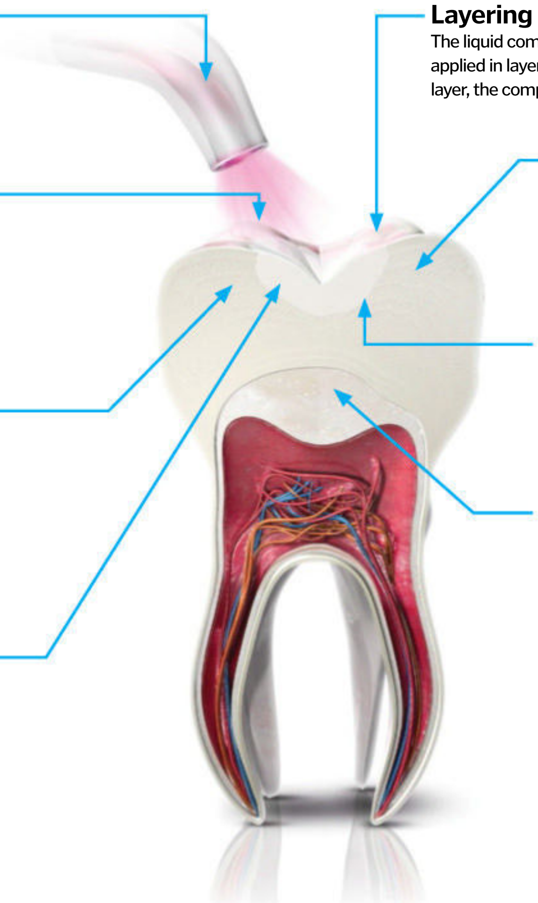
Composite resins are replacing traditional metal fillings, but what are they made of?

Curing
A light is used to trigger a chemical reaction within the resin, causing the material to harden.

Finishing touches
A piece of carbon paper is used to test whether the bite lines up properly, and the filling is smoothed down accordingly.

Primer
A priming agent is brushed onto the prepared tooth surface to enable the filling to adhere properly.

Decay
The decayed portion of the tooth is removed using a high-speed drill; this generates a solid platform for the filling to stick to.



Layering
The liquid composite resin is applied in layers. After each layer, the composite is cured.

Composite resin
Dental composites are made from a resin matrix that contains inorganic materials, such as silica, for durability.

Acid
A controlled amount of acid is applied to the drilled tooth to generate micro-holes for the filling to bind to.

Base
In deeper fillings, a cement base made from glass ionomer or zinc phosphate is added to insulate the nerve from temperature changes.

Is metal bad?

Traditional silver-coloured 'amalgam' fillings are made from mixed metals, and are often comprised of around 50 per cent mercury. Historical evidence suggests that this type of filling has been in use since around 650 A.D, and despite the advances in composite materials, the amalgam filling is still in use to this day.

There has been much controversy over the biological safety of amalgam fillings though, and concerns have been raised regarding mercury released into the body, as well as into the environment. However, as it stands, no causal link between health complaints and amalgam fillings has been proven. In fact, they still provide some advantages over composite fillings, and require significantly less repair and replacement.

Amalgam fillings require much less upkeep than their composite counterparts

What powers your cells?

Discover how mitochondria produce all the energy your body needs

Mitochondria are known as the batteries of cells because they use food to make energy. Muscle fibres need energy for us to move and brain cells need power to communicate with the rest of the body. They generate energy, called adenosine triphosphate (ATP), by combining oxygen with food molecules like glucose.

However, mitochondria are true biological multi-taskers, as they are also involved with signalling between cells, cell growth and the cell cycle. Theyperform all of these functions by regulating metabolism - the processes that maintain life - by controlling Krebs Cycle which is the set of reactions that produce ATP.

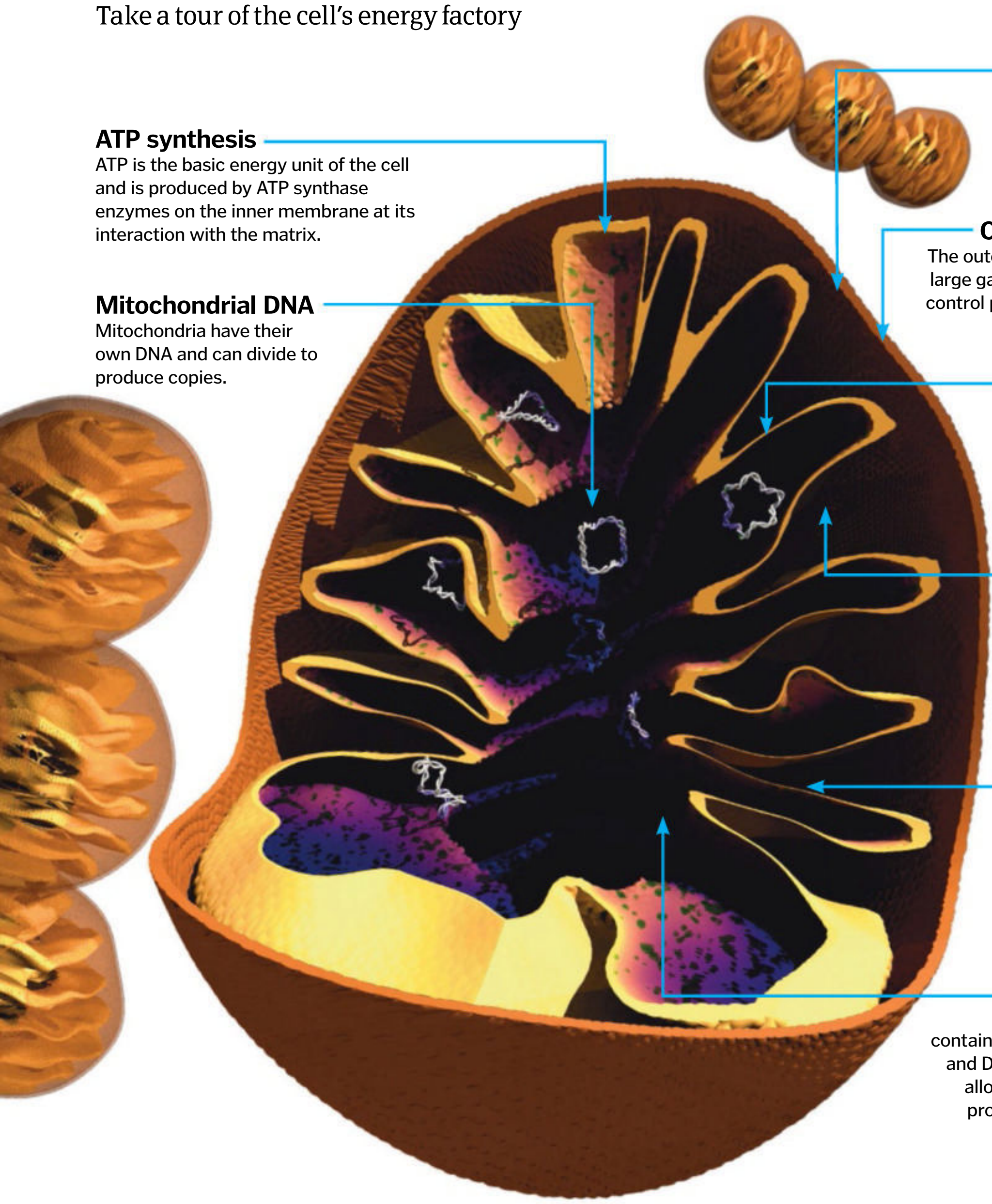
Mitochondria are found in nearly every cell in your body. They are found in most eukaryotic cells, which have nucleus and other organelles bound by a cell membrane. This means cells without these features, such as red blood cells, don't contain mitochondria. Their numbers also vary based on the individual cell types, with high-energy cells, like heart cells, containing many thousands. Mitochondria are vital for most life – human beings, animals and plants all have them, although bacteria don't.

They are deeply linked with evolution of all life. It is believed mitochondria formed over a billion years ago from two different cells, where the larger cell enveloped the other. The outer cell became dependent on the inner one for energy, while the inner cell was reliant on the outer one for protection.

This inner cell evolved to become a mitochondrion, and the outer cells evolved to form building blocks for larger cell structures. This process is known as the endosymbiotic theory, which is Ancient Greek for 'living together within.'

Inside the mitochondria

Take a tour of the cell's energy factory




Mitochondria produce fuel for everyday activities such as exercise

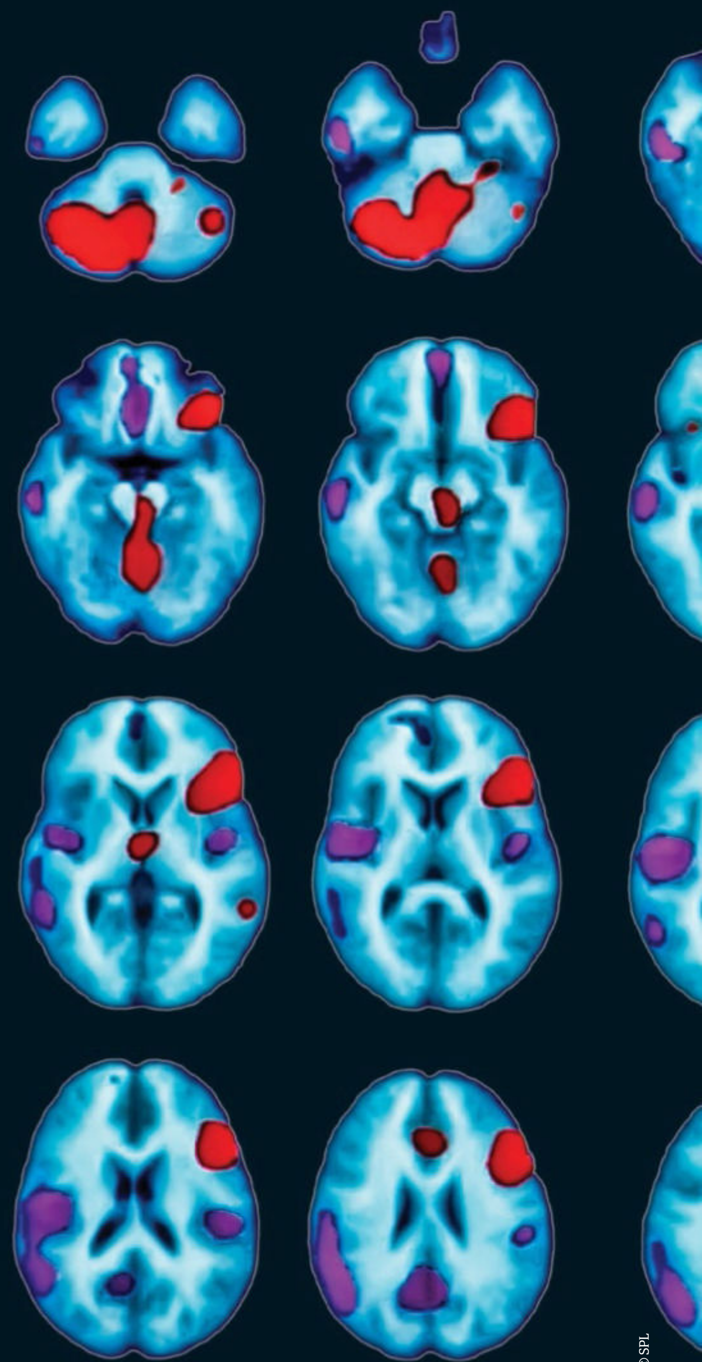
How many are in a cell?

The number of mitochondria in a cell depends on how active that particular cell is and how much energy it requires to function. As a general rule, they can either be low energy without a single mitochondrion, or high energy with thousands per cell. Examples of high-energy cells are heart muscles or the busy liver cells, which are active even when you're asleep, and are packed with mitochondria to keep functioning. If you train your muscles at the gym, those cells will develop more mitochondria as an adaptive mechanism to help provide energy.

Is it possible to see our thoughts?

The brain is perhaps the most vital of the body's vital organs, yet in many ways it's also the least understood

This CT scan of the brain has fused PET images over it, showing activity of different regions when the patient is exposed to a range of stimuli



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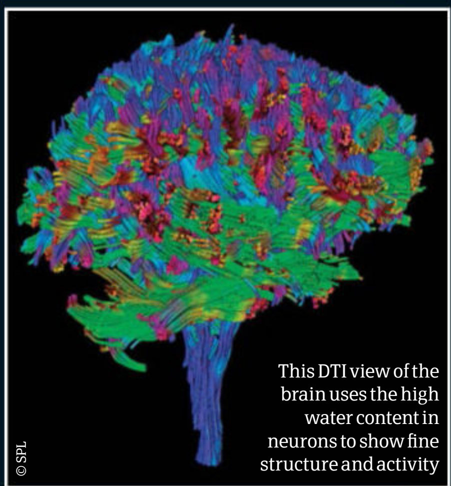
At its most simple level, the brain is a series of interconnecting neurons that relay electrical signals between one another. They are 'all or none' transmitters as, like a computer, they either transmit a signal (like a binary '1') or do not ('0'). Different neurons are receptive to different stimuli, such as light, touch and pain. The complex activity of these neurons is then interpreted by various parts of the brain into useful information. For example, light images from the eye are relayed via the optic nerve to the occipital cortex located in the back of the skull, for interpretation of the scene in front of you.

The generation and interpretation of thoughts is a more complex and less well understood process. In fact, it is a science of its own, where there are many definitions of what a 'thought' is, and of what defines consciousness. In an effort to better define these, doctors, scientists and psychologists have turned to novel imaging techniques to better understand the function of our minds. Research into understanding brain activity and function has led to some of the most advanced imaging techniques available. This has helped to treat conditions such as Alzheimer's dementia, epilepsy and stroke, as well as mental illnesses where there is not necessarily a physical problem within the brain. It has also led to benefits for imaging other diseases in other parts of the body, including several forms of cancer.

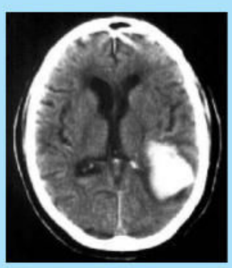


This DTI view of the brain uses the high water content in neurons to show fine structure and activity

© SPL

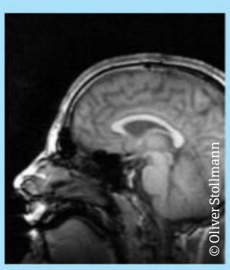
These advanced imaging techniques include scans to produce images of the anatomical structure of the brain, and interpretation of energy patterns to determine activity or abnormalities. Scientists have started to ascertain which parts of the brain function as we form different thoughts and experience different emotions. This means we are very much on the brink of seeing our own thoughts.

How can we view the brain?



Computed tomography (CT)

This combines multiple X-rays to see the bones of the skull and soft tissue of the brain. It's the most common scan used after trauma, to detect injuries to blood vessels and swelling. However, it can only give a snapshot of the structure so can't capture our thoughts.



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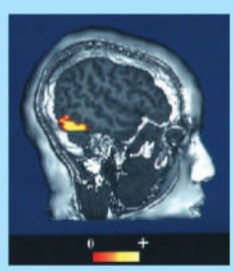
Magnetic resonance imaging (MRI)

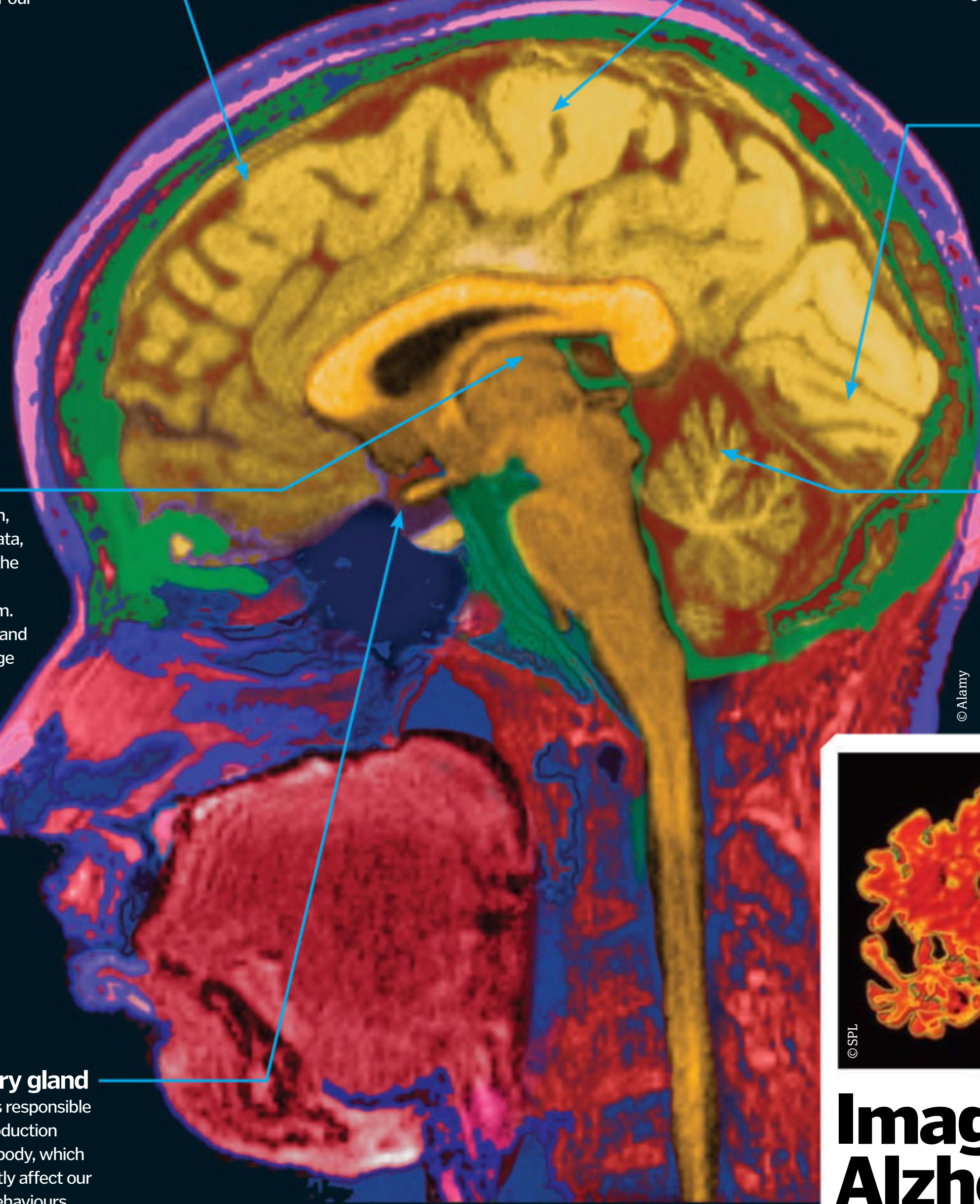
MRI uses strong magnetic fields to align the protons in water molecules in various body parts. When used in the brain, it allows intricate anatomical detail to be visualised. It has formed the basis of novel techniques to visualise thought processes.



Functional MRI (fMRI)

This form of MRI uses blood-oxygen-level-dependent (BOLD) contrast, followed by a strong magnetic field, to detect tiny changes in oxygen-rich and oxygen-poor blood. By showing pictures to invoke certain emotions, fMRI can reveal which areas are active during particular thoughts.

Picking apart the brain



The frontal lobes
The frontal lobes of the folded cerebral cortex take care of thought, reasoning, decisions and memories. This area is believed to be largely responsible for our individual personalities.

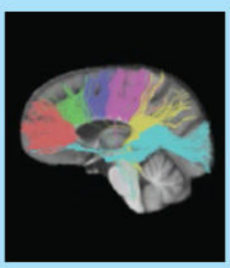
The sensory and motor cortexes
The pre- and post-central gyri receive the sensory information from the body and then dispatch orders to the muscles, in the form of signals through motor neurons.

The occipital cortex
In the posterior fossa of the skull, this cortex receives impulses from the optic nerves to form images. These images are in fact seen upside down, but this area enables them to be interpreted the right way up.

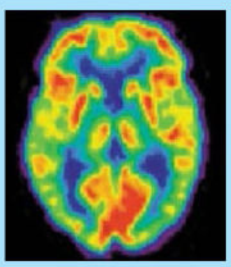
The brainstem
Formed from the midbrain, pons and medulla oblongata, the brainstem maintains the vital functions without us having to think about them. These include respiration and heart function; any damage to it leads to rapid death.

The cerebellum
The cerebellum is responsible for fine movements and co-ordination. Without it, we couldn't write, type, play musical instruments or perform any task that requires precise actions.

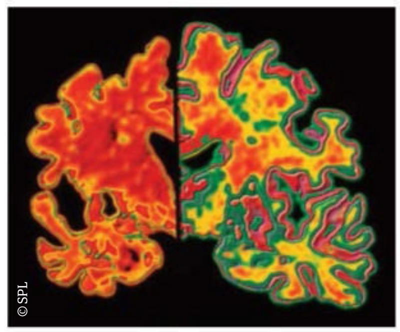
The pituitary gland
This tiny gland is responsible for hormone production throughout the body, which can thus indirectly affect our emotions and behaviours.



Diffusion tensor imaging (DTI)
This MRI variant relies on the direction of water diffusion within tissue. When a magnetic gradient is applied, the water aligns and, when the field is removed, the water diffuses according to a tissue's internal structure. This allows a 3D image of activity to be built up.



Positron emission tomography (PET)
This bleeding-edge technology detects gamma rays emitted from biologically active tissues based on glucose. It can pick up unusual biological activity, such as that from cancer. There have been recent advances to combine PET with CT or MRI to obtain lots of data quickly.



Imaging Alzheimer's
Alzheimer's disease is a potentially debilitating condition, which can lead to severe dementia. The ability to diagnose it accurately and early on has driven the need for modern imaging techniques. The above image shows a PET scan. The right-hand side of the image (as you look at it) shows a normal brain, with a good volume and activity range. On the left-hand side is a patient affected by Alzheimer's. The brain is shrunken with fewer folds, and a lower range of activity – biologically speaking, there are far fewer neurons firing.

How anaesthesia works

By interfering with nerve transmission these special drugs stop pain signals from reaching the brain during operations

Anaesthetics are a form of drug widely used to prevent pain associated with surgery. They fall into two main categories: local and general. Local anaesthetics can be either applied directly to the skin or injected. They are used to numb small areas without affecting consciousness, so the patient will remain awake throughout a procedure.

Local anaesthetics provide a short-term blockade of nerve transmission, preventing sensory neurons from sending pain signals to the brain. Information is transmitted along nerves by the movement of sodium ions down a carefully maintained electrochemical gradient. Local anaesthetics cut off sodium channels, preventing the ions from travelling through the membrane and stopping electrical signals travelling along the nerve.

Local anaesthesia isn't specific to pain nerves, so it will also stop information passing from the brain to the muscles, causing temporary paralysis.

General anaesthetics, meanwhile, are inhaled and injected medications that act on the central nervous system (brain and spinal cord) to induce a temporary coma, causing unconsciousness, muscle relaxation, pain relief and amnesia.

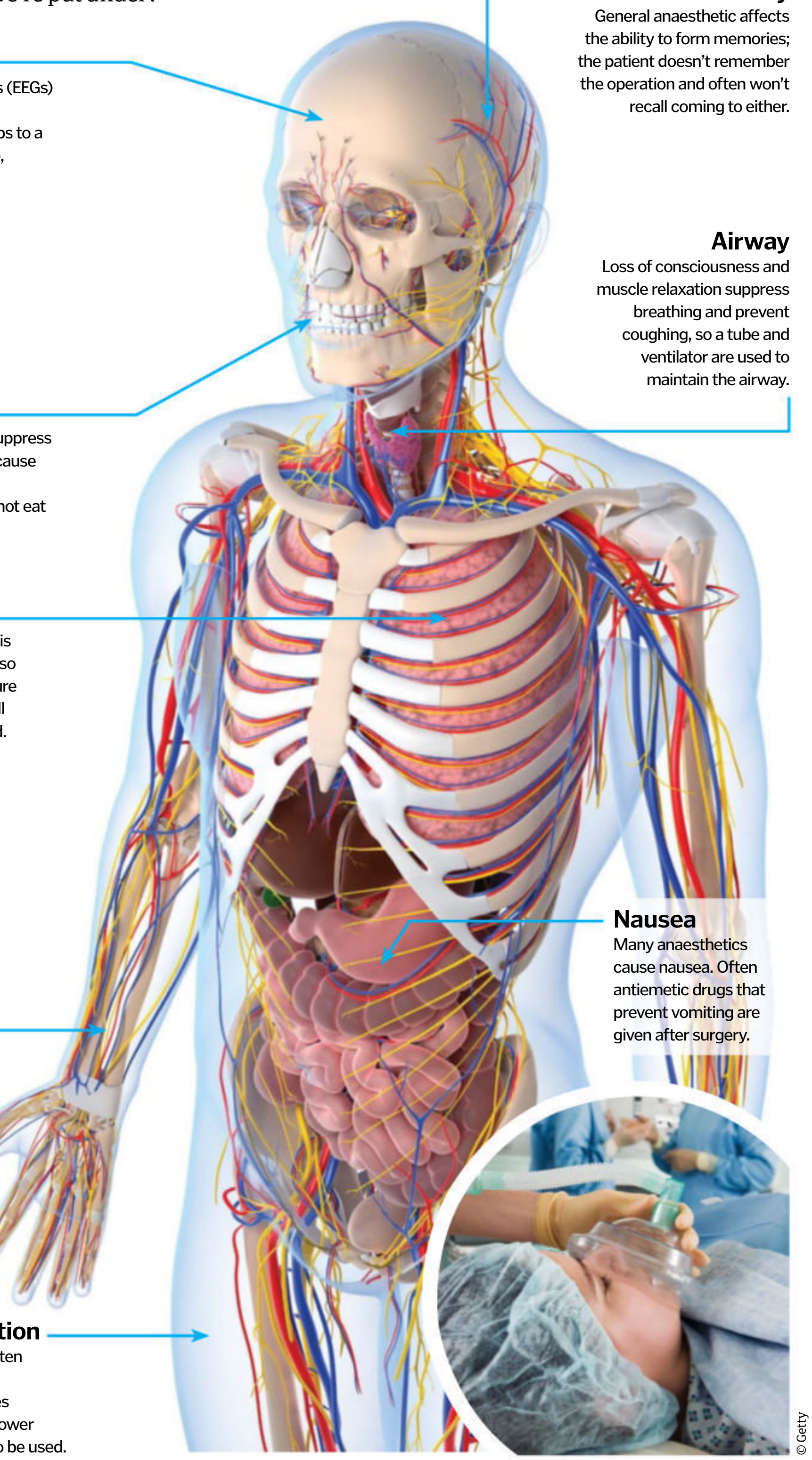
It's not known for sure how general anaesthetics 'shut down' the brain, but there are several proposed mechanisms. Many general anaesthetics dissolve in fats and are thought to interfere with the lipid membrane that surrounds nerve cells in the brain. They also disrupt neurotransmitter receptors, altering transmission of the chemical signals that let nerve cells communicate with one another.

Comfortably numb

If large areas need to be anaesthetised while the patient is still awake, local anaesthetics can be injected around bundles of nerves. By preventing transmission through a section of a large nerve, the signals from all of the smaller nerves that feed into it can't reach the brain. For example, injecting anaesthetic around the maxillary nerve will not only generate numbness in the roof of the mouth and all of the teeth on that side, but will stop nerve transmission from the nose and sinuses too. Local anaesthetics can also be injected into the epidural space in the spinal canal. This prevents nerve transmission through the spinal roots, blocking the transmission of information to the brain. The epidural procedure is often used to mollify pain during childbirth.

The body under general anaesthetic

What happens to various parts of the body when we're put under?



Brain activity
Electroencephalograms (EEGs) show that the electrical activity in the brain drops to a state deeper than sleep, mimicking a coma.

Memory
General anaesthetic affects the ability to form memories; the patient doesn't remember the operation and often won't recall coming to either.

Airway
Loss of consciousness and muscle relaxation suppress breathing and prevent coughing, so a tube and ventilator are used to maintain the airway.

Nil by mouth
General anaesthetics suppress the gag reflex and can cause vomiting, so to prevent choking patients must not eat before an operation.

Heart rate
The circulatory system is slowed by anaesthetic, so heart rate, blood pressure and blood oxygen are all continuously monitored.

Pain neurons
Unlike with local anaesthetic, pain neurons still fire under general anaesthesia, but the brain does not process the signals properly.

Nausea
Many anaesthetics cause nausea. Often antiemetic drugs that prevent vomiting are given after surgery.

Muscle relaxation
A muscle relaxant is often administered with the anaesthetic; this causes paralysis and enables lower doses of anaesthetic to be used.

What causes stomach ulcers?

Originally thought to be the result of stress, we now know that bacteria are the culprits…

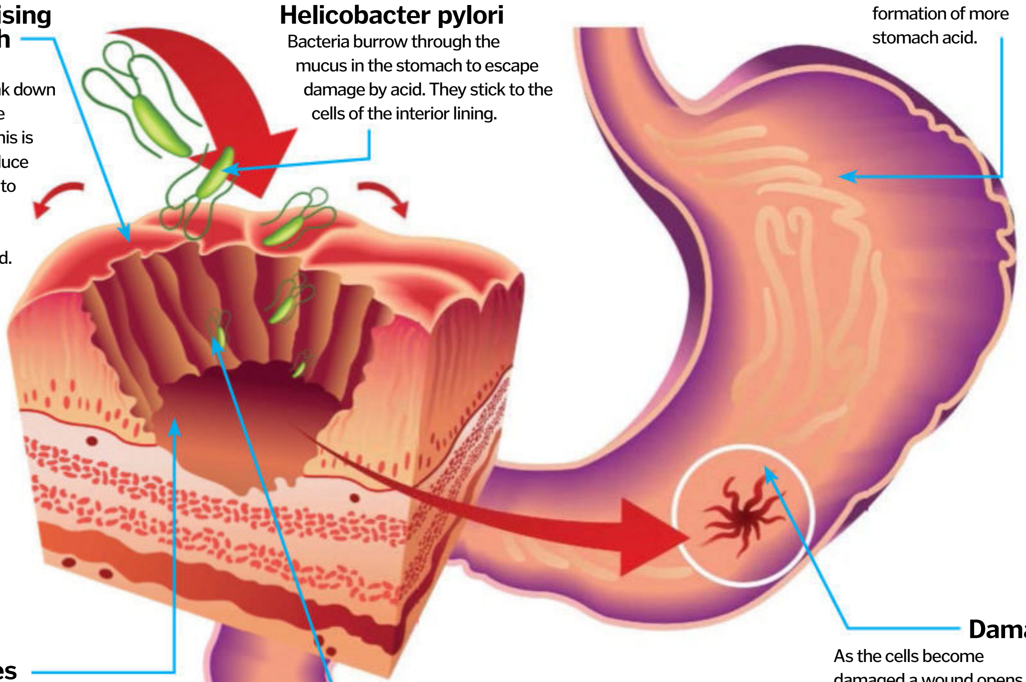
Normally a thick layer of alkaline mucus effectively protects the cells lining the stomach from the low pH of stomach acid. If this mucus becomes disrupted, however, acid comes into contact with the organ's lining, damaging the cells and resulting in an ulcer.

Around 60 per cent of stomach ulcers are caused by inflammation due to chronic infection by the bacterium Helicobacter pylori. Bacterial by-products damage the cells lining the stomach, causing a breakdown of the top layers of tissue.

Non-steroidal anti-inflammatory drugs (NSAIDs), like ibuprofen and aspirin, also cause stomach ulcers in large doses. They disrupt the enzymes responsible for mucus production, diminishing the protective barrier.

An ulcer in the making

Once bacteria breach the stomach lining, it can no longer protect itself from its acidic contents…



Neutralising stomach acid
H pylori break down urea to make ammonia. This is used to produce bicarbonate to neutralise dangerous stomach acid.

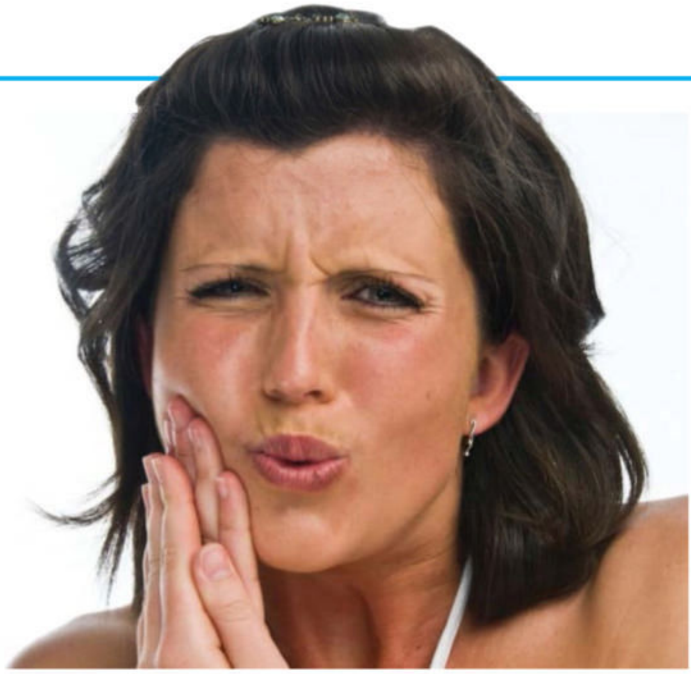
Helicobacter pylori
Bacteria burrow through the mucus in the stomach to escape damage by acid. They stick to the cells of the interior lining.

Gastrin
The inflammatory response increases production of the hormone gastrin. This in turn stimulates the formation of more stomach acid.

Enzymes
H pylori produce proteases and phospholipases – enzymes that damage the proteins and cell membranes of the stomach cells.

Ammonia
The ammonia made by the bacteria as a defence against acid damages the cells lining the stomach, causing inflammation.

Damage
As the cells become damaged a wound opens up in the stomach wall. If this becomes deep enough it can perforate blood vessels causing bleeding.



© Alamy

Why do we sometimes get mouth ulcers?

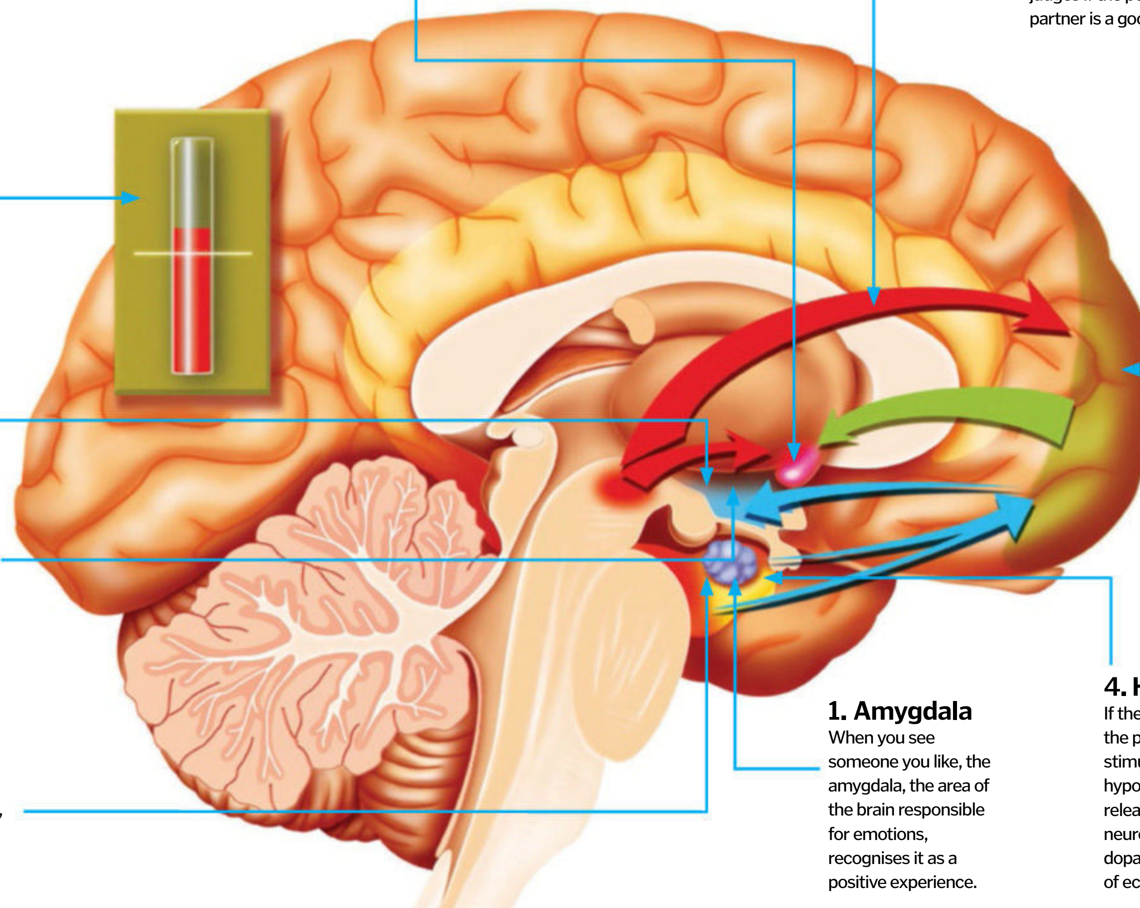
Ulcers are small lesions usually triggered by physical damage to the inside of the mouth, for example biting your cheek accidentally, eating sharp food or brushing your teeth. They are very rarely contagious and usually heal within ten days. Recurrent ulcers have a variety of causes, the most common being stress and hormonal changes.

In other cases, recurrent ulcers may be symptomatic of conditions including B12 or iron deficiencies, gastrointestinal diseases or immunosuppressant diseases such as HIV. Ulcers are sometimes triggered by sensitivity to certain foods including strawberries, almonds, tomatoes, cheese, chocolate and coffee.

"They are rarely contagious and usually heal in ten days"

Why do we feel love?

The hormones and chemicals that cause us to fall head over heels



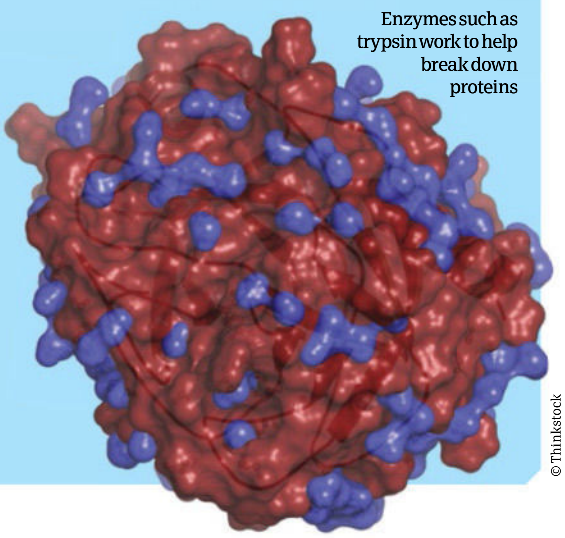
How do enzymes keep you alive?

The proteins that speed up your body's chemical reactions

Enzymes increase the speed of reactions that take place inside cells by lowering the energy-activation requirement for molecular reactions. Molecules need to react with each other to reproduce, but our bodies provide neither the heat nor the pressure required for these reactions.

Each cell contains thousands of enzymes, which are amino acid strings rolled up into a ball called a globular protein. Each enzyme contains a gap called an active site into which a molecule can fit. Once inside the crack, the molecule – which becomes known as a substrate – undergoes a reaction such as dividing or merging with another molecule without having to expel energy in a collision with another molecule. The enzyme releases it and floats on within the cell's cytoplasm. The molecule and active site need to match up perfectly in order for the sped-up reaction to take place. For example, a lactose molecule would fit into a lactase enzyme's active site, but not that of a maltase enzyme.

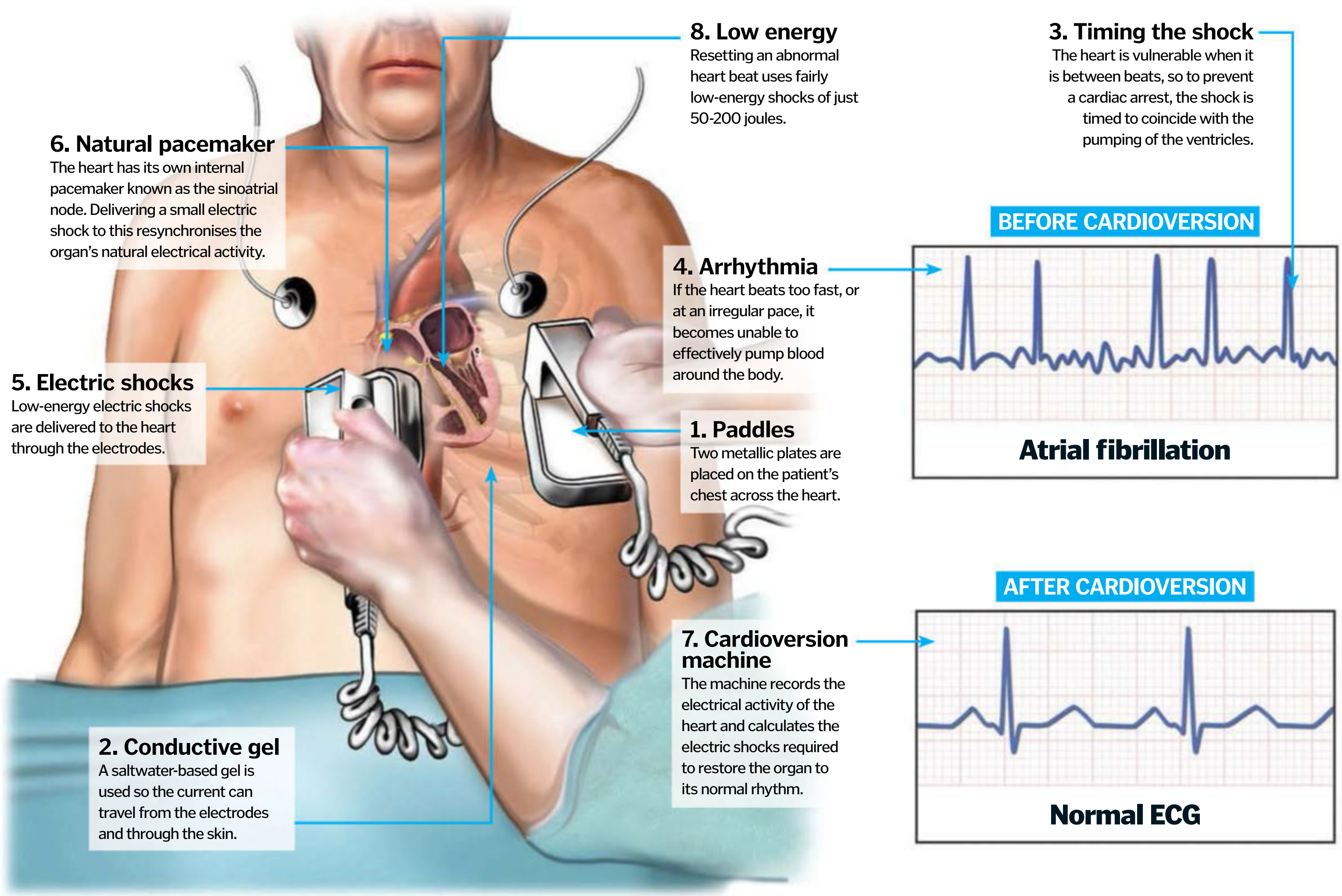
Interestingly enough, enzymes don't get used up in the process, so they can theoretically continue to speed up reactions indefinitely.



Enzymes such as trypsin work to help break down proteins

Correcting heart rhythms

How can a little electricity be used to fix a heart that's beating off-kilter?



Why's salt bad for the heart?

Simply put, too much salt is bad for you as it increases the demand on your heart to pump blood around the body. This is because when you eat salt it causes retention of increased quantities of water, which increases your blood pressure, and this places more strain on your heart. Most doctors recommend moderating salt intake.

Do women have Adam's apples?

You may not realise, but actually everyone has an Adam's apple, but men's are usually easier to see in their throat. It's a bump on the neck that moves when you swallow, named after the biblical Adam. Supposedly, it's a chunk of the Garden of Eden's forbidden fruit stuck in his descendants' throats, but it's actually a bump on the thyroid cartilage surrounding the voice box. Thyroid cartilage is shield-shaped and the Adam's apple is the bit at the front.

Why do men's Adam's apples stick out more? This is partly because they have bonier necks, but it is also because their larynxes grow differently from women's during puberty to accommodate their longer, thicker vocal cords, which give them deeper voices.

What causes a rumbling stomach?

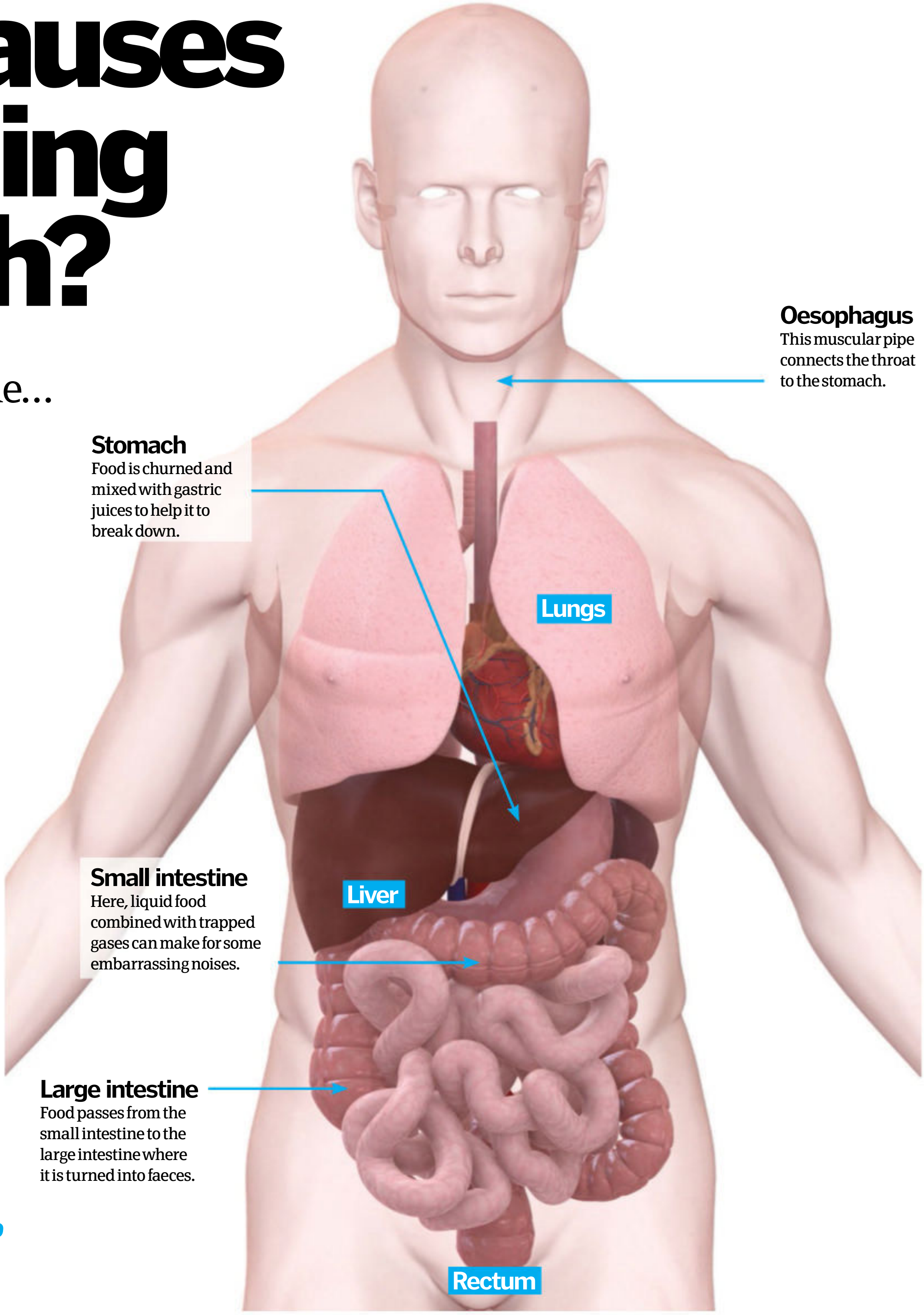
Discover how the small intestine is really to blame…

Waves of involuntary muscle contractions called peristalsis churn the food we eat to soften it and transport it through the digestive system. The contractions are caused by strong muscles in the oesophagus wall, which take just ten seconds to push food down to the stomach. Muscles in the stomach churn food and gastric juices to break it down further.

Then, after four hours, the semi-digested liquefied food moves on to the small intestine where yet more powerful muscle contractions force the food down through the intestine's bends and folds. This is where the rumbling occurs. Air from gaseous foods or that swallowed when we eat – often due to talking or inhaling through the nose while chewing food – also ends up in the small intestine, and it's this combination of liquid and gas in a small space that causes the gurgling noise.

Rumbling is louder the less food present in the small intestine, which is partly why people associate rumbling tummies with hunger. The other reason is that although the stomach may be clear, the brain still triggers peristalsis at regular intervals to rid the intestines of any remaining food. This creates a hollow feeling that causes you to feel hungry.

"After four hours, the semi-digested liquefied food moves to the small intestine"



Are seasickness and altitude sickness the same thing?

No, they're not – altitude sickness is a collection of symptoms brought on when you're suddenly exposed to a high-altitude environment with lower air pressure so less oxygen enters our body. The symptoms can include a headache, fatigue, dizziness and nausea.

Seasickness, on the other hand, is a more general feeling of nausea that's thought to be caused when your brain and senses get 'mixed signals' about a moving environment – for instance, when your eyes tell you that your immediate surroundings (such as a ship's cabin) are still as a rock, while your sense of balance (and your stomach!) tells you something quite different.

This is the reason why closing your eyes or taking a turn out on deck will often help, as it reconciles the two opposing sensations.

How do cravings work?

Is a child destined to develop a taste for all things sweet?

Hunger and cravings are two very different things. While one is about survival, the other satisfies the nagging need for something sugary. It's believed we all develop a taste for sweetness in infancy. This stems from the predominant sweet taste of our mother's milk; when we taste it, the brain's reward centres light up, causing us to derive pleasure from this experience. As we continue to consume our mother's milk this pleasure is reinforced, which could explain how our sugar cravings originate.

Our mothers' diet can influence our preferences for certain foods. Scientists have found that flavours are transmitted from mother to baby via the amniotic fluid surrounding the foetus in the womb. Once born, the probability of the child disliking the flavours they have already experienced is reduced.

Our gut also plays a large role in cravings. The gut contains an almost separate autonomous system that governs the digestion lining. This vast network of 100 million neurones constantly samples the ingested food, relaying this information to the brain. This endless conversation can cause our appetite and cravings to change. The gut bacteria are also heavily involved; when they break down large quantities of fibre, they produce a specific compound that is sent to the brain, triggering it to feel full and satisfied from the recently ingested meal.

So should we consider cravings as a sign of food addiction? Although high-sugar and high-fat foods exhibit some of the hallmarks of addiction, the consensus is that it's actually the behaviour around eating these foods that we are addicted to.

People commonly crave the sweet taste and melt-in-the-mouth texture of chocolate

Can the latest technology stop cravings?

One of the most recent inventions is a microchip that aims to control cravings, developed by Kings College London's Centre for Bio-Inspired Technology. Once implanted in the body, the chip will use electrodes to monitor the signals that are consistently passing between the gut and the brain. By 'listening' to the communication between the two organs, the microchip will be able to recognise signals for cravings and alter these before they reach the brain.

Ghrelin is the body's hunger-inducing hormone. By using a ghrelin antagonist, scientists aim to suppress this hormone's activity, stopping cravings from ever materialising. This research has implications for cravings of other substances too. Scientists have hypothesised that due to the similarities between this system and that responsible for craving nicotine and alcohol, it may be possible to switch off these cravings as well as those related to food.

Tricking our senses

Does a spoon's colour change the way yoghurt tastes? In reality it doesn't, but the colour of cutlery can alter how you think something tastes. A recent study fed a group of volunteers the same yoghurt using a white and a black spoon. The results showed that the yoghurt was perceived to taste sweeter on the white spoon. Altering the spoon's weight was then tested. The lighter spoons caused the participants to feel the yoghurt was denser and more luxurious. Scientists are unsure what mechanism causes these bizarre results, and want to carry out further research into why we make these associations.

What causes the knee-jerk reaction?

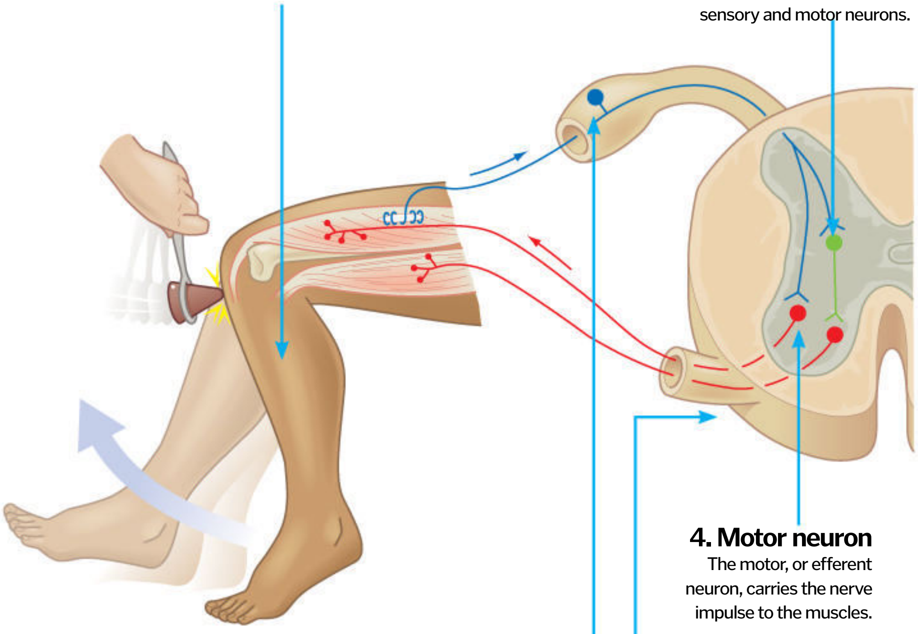
Why does your leg kick out when the doctor taps just below your knee?

Doctors often test the knee-jerk, or patellar reflex, to look for potential neurological problems. Lightly tapping your patellar tendon just below the kneecap stretches the femoral nerve located in your thigh, which in turn causes your thigh muscle (quadriceps) to contract and the lower leg to extend. When struck, impulses travel along a pathway in the dorsal root ganglion, a bundle of nerves in the L4 level of the spinal cord. Reflex actions are performed independently of the brain. This allows them to happen almost instantaneously – within about 50 milliseconds in the case of the knee-jerk reflex. This reflex helps you to maintain balance and posture when you walk, without having to think about every step you take.

The knee-jerk step-by-step

1. Quadriceps and hamstring muscles
The knee-jerk reflex means that the quadriceps muscles contract at the same time the hamstring muscle relaxes.

3. Interneuron
The interneuron provides a connection between the sensory and motor neurons.



4. Motor neuron
The motor, or efferent neuron, carries the nerve impulse to the muscles.

5. Spinal cord
The spinal cord has both grey matter, which contains nerve cell bodies, and white matter, which contains the nerve fibres.

2. Sensory neuron
The sensory, or afferent neuron, receives an impulse from the femoral nerve.

Sensory neuron
Motor neuron
Interneuron

"Reflex actions are performed independently of the brain"

Why do feet smell?

Producing up to a pint of sweat each day, no wonder your feet get a bit whiffy

Sweat actually keeps the skin of our feet moist and flexible to cope with the constantly changing pressure when we walk. Without this moisture the skin would dry and crack, and walking would become extremely painful. Despite the huge number of glands (250,000 per foot) and amount of sweat that comes from our feet, remember it's still just salt and water. The odour comes from the bacteria that live on human skin which, while unsettling, are perfectly natural.

Our socks are a dark, moist-infested feast for them, as they eat sweat and dead skin. It is the waste products they excrete from this consumption that are what smells bad. The more the bacteria eat the worse our feet smell. To keep the smell down, make sure you change your socks and let your shoes air for 24 hours if you can. Also, wash your feet and spray them with antiperspirant!

The wonderful smell of freshly cut grass, daisies and feet...

Blisters shouldn't be burst as they are the body's way of protecting deeper skin layers

What are blisters?

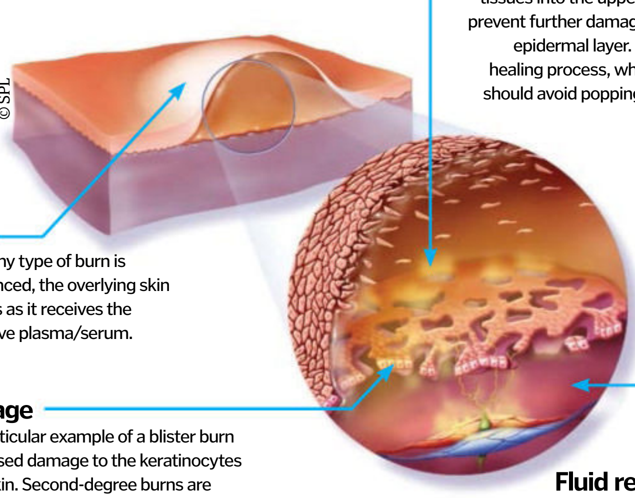
Why do burns cause bubbles to develop below the surface of the skin?

Though our skin is an amazing protector against the elements, it can become damaged by such factors as heat, cold, friction, chemicals, light, electricity and radiation, all of which 'burn' the skin. A blister is the resulting injury that develops in the upper layers of the skin as a result of such burns.

The most common example of a blister, which we've no doubt all experienced at some time, is due to the repeated friction caused by the material of a pair of shoes rubbing against, and irritating, the skin. The resulting water blister is a kind of plasma-filled bubble that appears just below the top layers of your skin. The plasma, or serum – which is a component of your blood – is released by the damaged tissue cells and fills the spaces between the layers of skin to cushion the underlying skin and protect it from further damage. As more and more serum pours into the space, the skin begins to inflate under the pressure, forming a small balloon full of the serous liquid. Given time to heal, the skin will reabsorb the plasma after about 24 hours.

Similarly, a blood blister is a variation of the same injury where the skin has been forcefully pinched or crushed but not pierced, causing small blood vessels to rupture, leaking blood into the skin. All blisters can be tender but should never be popped to drain the fluid as this leaves the underlying skin unprotected and invites infection into the open wound.

Blister caused by second-degree burns



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Plasma
Serum is released by the damaged tissues into the upper skin layers to prevent further damage below in the epidermal layer. It also aids the healing process, which is why you should avoid popping your blisters.

Skin
When any type of burn is experienced, the overlying skin expands as it receives the protective plasma/serum.

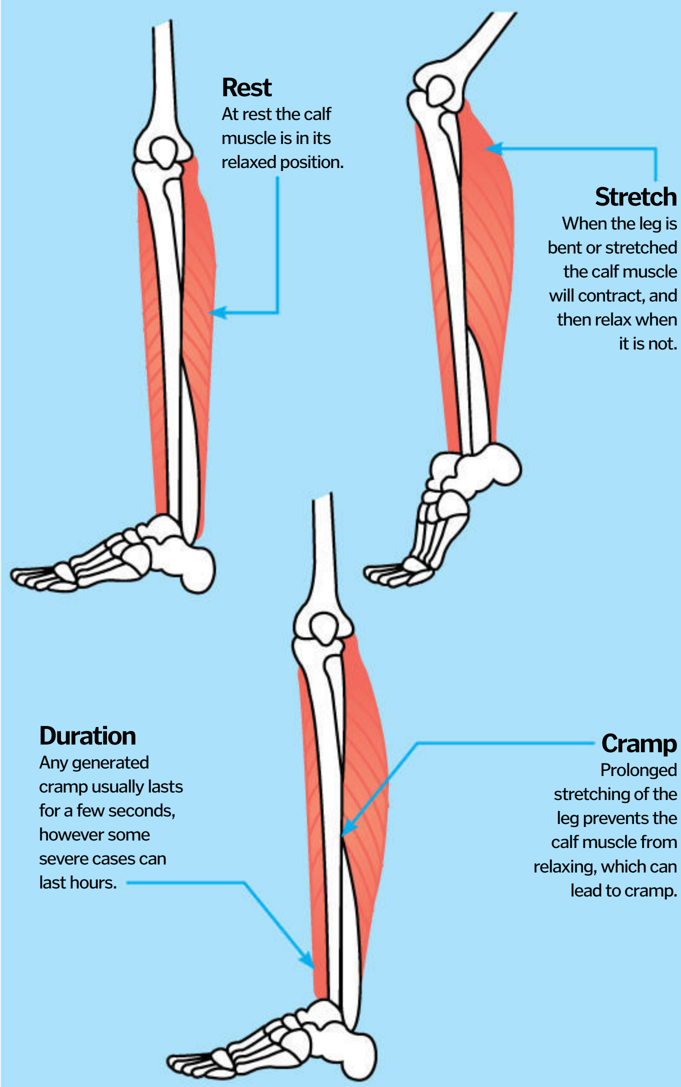
Damage
This particular example of a blister burn has caused damage to the keratinocytes in the skin. Second-degree burns are most often caused when the skin comes into contact with a hot surface, such as an iron or boiling water, or even after exposure to excessive sunlight.

Fluid reabsorbed
After a day or so the serum will be absorbed back into the body and the raised skin layers will dry out and flake off in their own time.

Cramp explained

Why do our muscles tense up?

Cramp is an involuntary contraction of a muscle, often in a limb such as the leg, that can cause pain and discomfort for seconds, minutes or, in extreme cases, for several hours. They are most common after or during exercise, coinciding with low blood sugar levels, dehydration and a high loss of salt from sweating. Although the full range of causes is something of a mystery due to limited research in the area, cramp is believed to be the result of muscle fatigue. If a muscle has been shortened through prolonged use, but is repeatedly stimulated, it isn't able to properly relax. A reflex arc from the central nervous system to the muscle informs it to continue contracting when it is not necessary, leading to a painful spasm known as cramp as the muscle continually attempts to contract. This is why athletes pushed beyond their limits, such as football players who have to play extra time in a match, will often experience this condition.



Do we control our brains or do our brains control us?

An experiment at the Max Planck Institute, Berlin, in 2008 showed that when you decide to move your hand, the decision can be seen in your brain, with an MRI scanner, before you are aware you have made a decision. The delay is around six seconds. During that time, your mind is made up but your consciousness doesn't acknowledge the decision until your hand moves. One interpretation of this is that your consciousness – the thing you think of as 'you' – is just a passenger inside a deterministic automaton. Your unconscious brain and your body get on with running your life, and only report back to your conscious mind to preserve a sense of free will. But it's just as valid to say that when you make a decision, there's always background processing going on, which the conscious mind ignores for convenience. In the same way, your eye projects an upside-down image onto your retina, but your unconscious brain turns it the right way around.

Gelotology is the study of laughter and its effects on the human body

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What happens when we laugh?

Which muscles react when we find something funny and why is laughter so hard to fake?

Laughing can sometimes be completely involuntary and involves a complex series of muscles, which is why it's so difficult to fake and also why an active effort is required to suppress laughter in moments of sudden hilarity at inopportune moments.

In the face, the zygomaticus major and minor anchor at the cheekbones and stretch down towards the jaw to pull the facial expression upward; on top of this, the zygomaticus major also pulls the upper lip upward and outward.

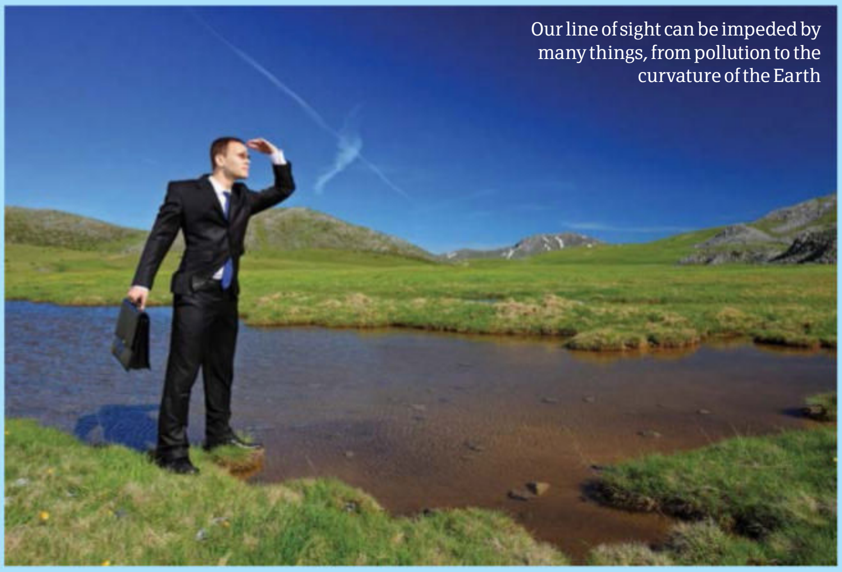
The sound of our laugh is produced by the same mechanisms which are used for coughing and speaking: namely, the lungs and the larynx. When we're breathing normally, air from the lungs passes freely through the completely open vocal cords in the larynx. When they close, air cannot pass, however when they're partially open, they generate some form of sound. Laughter is the result when we exhale while the vocal cords close, with the respiratory muscles periodically activating to produce the characteristic rhythmic sound of laughing.

The risorius muscle is used to smile, but affects a smaller portion of the face and is easier to control than the zygomatic muscles. As a result, the risorius is more often used to feign amusement, hence why fake laughter is easy to detect by other humans.

"Laughter is produced by the same mechanisms used for coughing and speaking"

What is the maximum distance the human eye can see?

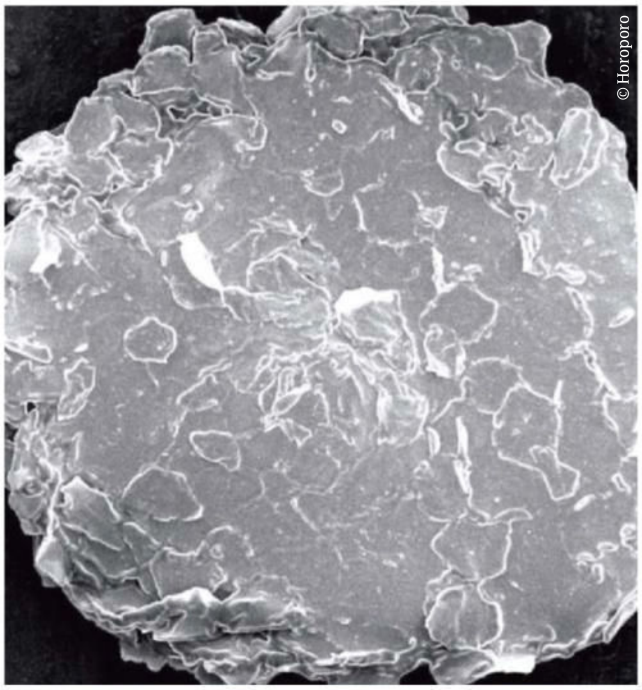
Dust, water vapour and pollution in the air will rarely let you see more than 20 kilometres, even on a clear day. Often, the curvature of the Earth gets in the way first – eg at sea level, the horizon is only 4.8km away. On the top of Mt Everest, you could theoretically see for 339km, but in practice cloud gets in the way. For a truly unobstructed view, look up. On a clear night, you can see the Andromeda galaxy with the naked eye, which is 2.25 million light years away.



Our line of sight can be impeded by many things, from pollution to the curvature of the Earth

What is dandruff?

Dandruff is when dead skin cells fall off the scalp. This is normal, as our skin is always being renewed. About half the population of the world suffers from an excessive amount of this shedding, which can be triggered by things like temperature or the increased activity of a microorganism that normally lives in everyone's skin, known as malassezia globosa. Dandruff is not contagious and there are many treatments available, the most common is specialised shampoo.



Why do eyes take a while to adjust to dark?

At the back of the eye on the retina, there are two types of photoreceptors (cells which detect light). Cones deal with colour and fine detail and act in bright light, while rods deal with vision in low-light situations. In the first few minutes of moving into a dark room, cones are responsible for vision but provide a poor picture. Once the rods become more active, they take over and create a much better picture in poor light. Once you move back into light, the rods are reset and so dark-adaption will take a few moments again. Soldiers are trained to close or cover one eye at night when moving in and out of a bright room, or when using a torch, to protect their night vision. Once back in the dark, they reopen the closed eye with the rods still working and, as a result, maintain good vision. This allows them to keep operating in a potentially hostile environment at peak operational efficiency. Give it a try next time you get up in the middle of the night, it may help you avoid tripping over in the dark.

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Why do some people have allergies and some don't?

Allergies can be caused by two things: host and environmental factors. Host is if you inherit an allergy or are likely to get it due to your age, sex or racial group. Environmental factors can include things such as pollution, epidemic diseases and diet.

People who are likely to develop allergies have a condition known as 'atopy'. Atopy is not an illness but an inherited feature, which makes individuals more likely to develop an allergic disorder. Atopy tends to run in families.

The reason why atopic people have a tendency to develop allergic disorders is because they have the ability to produce the allergy antibody called 'Immunoglobulin E' or 'IgE' when they come into contact with a particular substance. However, not everyone who has inherited the tendency to be atopic will develop an allergic disorder.

"People who are likely to develop allergies have a condition known as 'atopy'"

Eczema explained

What causes the skin to react to otherwise harmless material?

Eczema is a broad term for a range of skin conditions, but the most common form is atopic dermatitis. People with this condition have very reactive skin, which mounts an inflammatory response when in contact with irritants and allergens. Mast cells release histamine, which can lead to itching and scratching, forming sores open to infection.

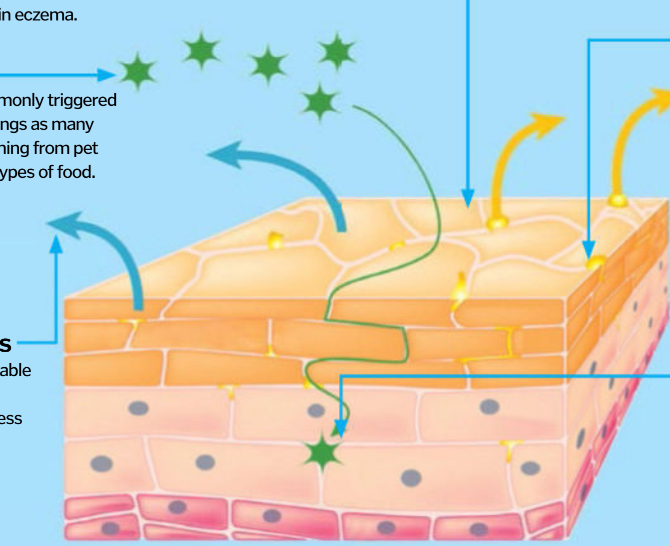
There is thought to be a genetic element to the disease and a gene involved in retaining water in the skin has been identified as a potential contributor, but there are many factors.

Eczema can be treated with steroids, which suppress immune system activity, dampening the inflammation so skin can heal. In serious cases, immunosuppressant drugs – used to prevent transplant rejection – can actually be used to weaken the immune system so it no longer causes inflammation in the skin.

The histamine increase can cause itching, leading to open sores

Under the skin

What happens inside the body when eczema flares up?



Ceramides
The membranes of skin cells contain waxy lipids to prevent moisture evaporation, but these are often deficient in eczema.

Allergen
Eczema is commonly triggered by the same things as many allergies – anything from pet hair to certain types of food.

Water loss
The skin is less able to retain water, leading to dryness and irritation.

Allergen entry route
The cells of the skin are normally tightly bound together to prevent contaminants from entering the body, but in eczema there are gaps.

Inflammatory response
The immune system produces a response to allergens beneath the skin, leading to redness, itching and also inflammation.

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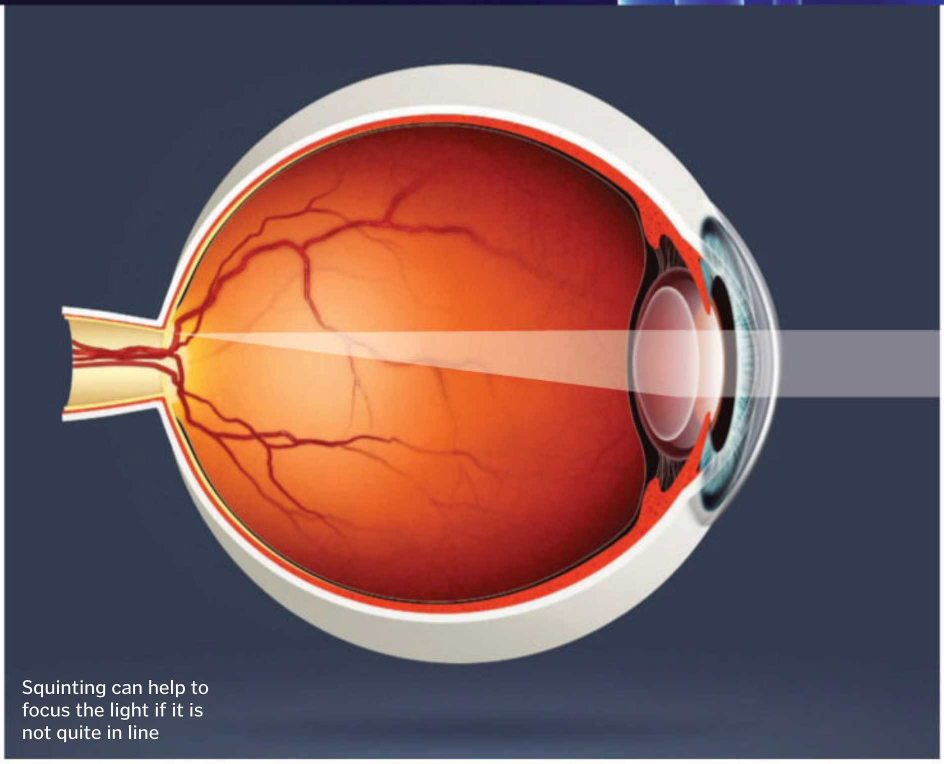
It turns out that growing pains don't have much to do with growth after all

What are growing pains?

The medical name for growing pains is 'recurrent nocturnal limb pain in children', and it describes the sensation of aching, crampy pain most often felt at night in the lower half of the legs.

Children and preteens are often told that they experience these aches and pains because they are growing, but this is untrue. If the pain really were caused by growth itself, doctors would expect to be visited by children that were going through a growth spurt, but there does not seem to be any link between periods of rapid bone growth and experience of 'growing pains'.

The pain is not in the bones or joints but is actually in the muscles and soft tissues, and one of the best explanations is that the pain is the result of strain or overuse of the muscles and joints during the day.



Squinting can help to focus the light if it is not quite in line

Why can we see clearer when we squint?

It doesn't work for everyone, but for some people things come into focus when they half close their eyes. This is because of the way that the eye focuses light.

A flexible lens bends the light as it passes into the eye, focusing it on a highly sensitive spot on the retina, called the fovea. The lens changes shape depending on the distance to the object, ensuring that the light is always concentrated on this spot.

As we get older, the lens becomes less flexible and cannot focus the light as well. By half closing our eyelids, we can put a little pressure on our eyeballs, changing their shape manually and helping to bring the light into focus.

Monozygotic twins are a rarity

What are twins?

Twins are becoming more prevalent due to medical developments, but how and why do they occur?

The number of twins, or multiples, being born is actually on the rise due to the increase in use of fertility treatments such as IVF as people wait longer to have children. The number of twins surviving early births is also increasing due to improved medical knowledge.

However, twins are still a relatively rare occurrence making up only around two per cent of the living world's population. Within this, monozygotic twins (from one ovum) make up around eight per cent with dizygotic (from two ovum) seen to be far more common.

While there is no known reason for the occurrence of the split of the ovum that causes monozygotic twins, the chances of having twins is thought to be affected by several different factors. It is believed twins 'run in the family', often seeming to skip generations, while the age, weight, height, race and even diet of the mother are thought to potentially impact the chances of conceiving dizygotic twins. Also, if the mother is going through fertility treatments, she is much more likely to become pregnant with multiples.

It will become apparent quite early on that a mother is carrying twins as this is often picked up during early ultrasound scans. There can be other indications such as increased weight gain or extreme fatigue. Although twins are often born entirely healthy and go on to develop without problems later in life due to medical advances, twins can be premature and smaller than single births due to space constrictions within the womb during development.

> "It is believed twins 'run in the family', often seeming to skip generations"

Strange, but true…

There are many stories of identical twins being separated at birth and then growing up to lead very similar lives. One example described in the 1980 January edition of *Reader's Digest* tells of two twins separated at birth, both named James, who both pursued law-enforcement training and had a talent for carpentry. One named his son James Alan, and the other named his James Allan and both named their dogs Toy. There were also the Mowforth twins, two identical brothers who lived 80 miles apart in the UK, dying of exactly the same symptoms on the same night within hours of each other.

DID YOU KNOW? *Female monozygotic twins are more common due to the increased likelihood of male mortality in the womb*

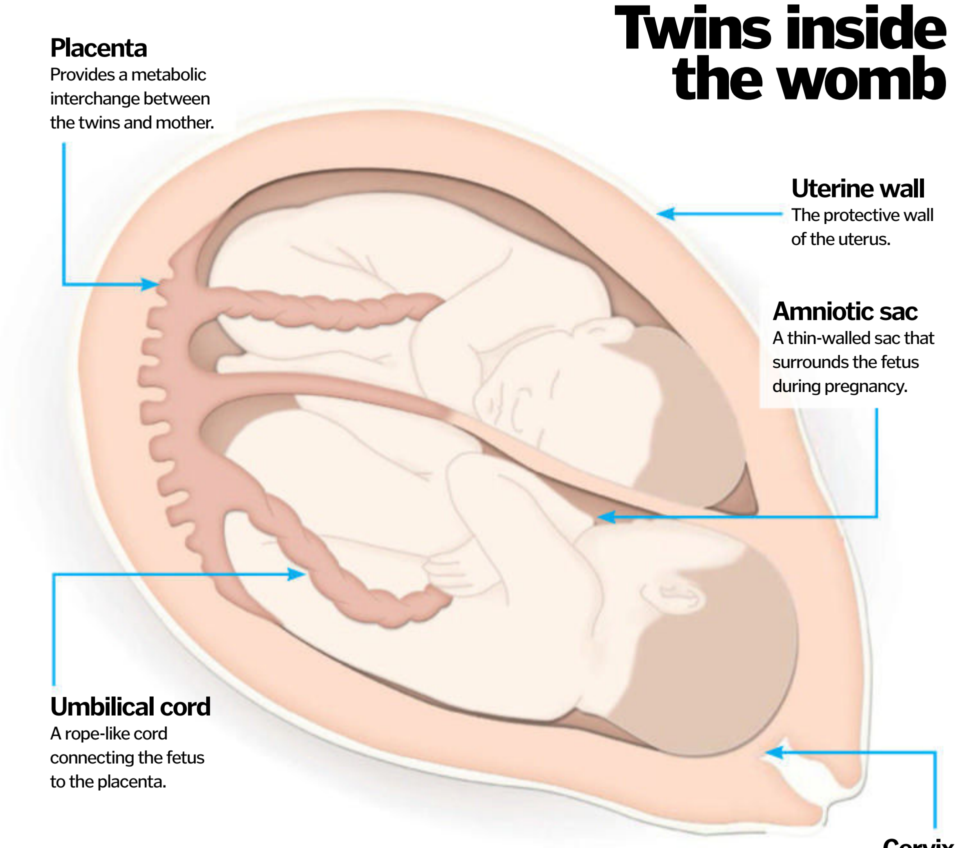
Multiple pregnancies, multiple problems?

There are many difficulties with twin pregnancies – mainly due to the limited size of the mother's womb. Multiple pregnancies rarely reach full term due to these limits, twins averaging at around 37 weeks. Also, because of the lack of space and eggs splitting in the womb, further complications such as conjoined twins can occur. Conjoined twins can be a problem dependant on where they're joined. If it is by a vital organ or bone structure, one or both may die following birth as they grow – or during an operation to separate them.

It is also suspected that as many as one in eight pregnancies may have started out as a potential multiple birth, but one or more of the foetuses does not progress through development to full term.

> *"Conjoined twins can be a problem dependant on where they're joined"*

Twins inside the womb



Genetically identical, but why do twins differ?

From studying identical, monozygotic twins, we can attempt to decipher the level of impact environment has on an individual and the influence genes have. As the genetics of the individuals would be identical, we can say that differences displayed between two MZ twins are likely to be down to environmental influences.

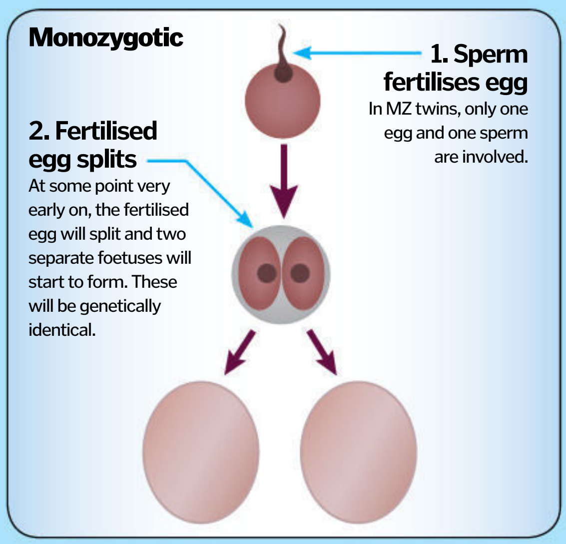
Some of the most interesting studies look at twins that have been separated at birth, often when individuals have been adopted by different parents. Often we see a similar IQ and personality displayed, whether or not they grow up together, but even these and other lifestyle choices can vary dependant on environment.

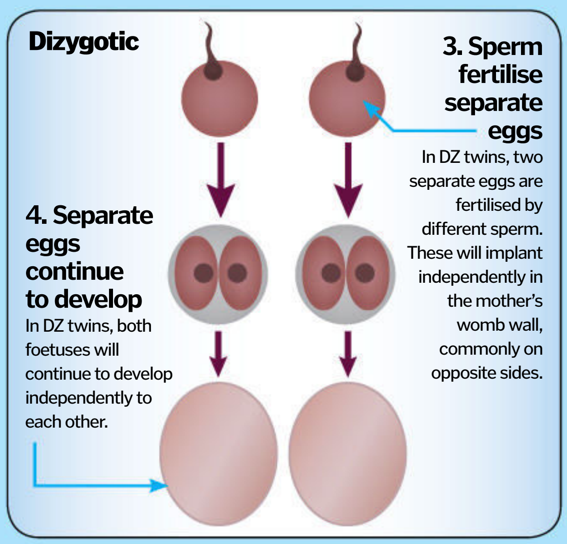
Ultimately, it is hard to draw firm conclusions from twin studies as they will be an unrepresentatively small sample within a much larger population and we often find that both environment and genetics interact to influence an individual's development.

Formation of identical and fraternal twins

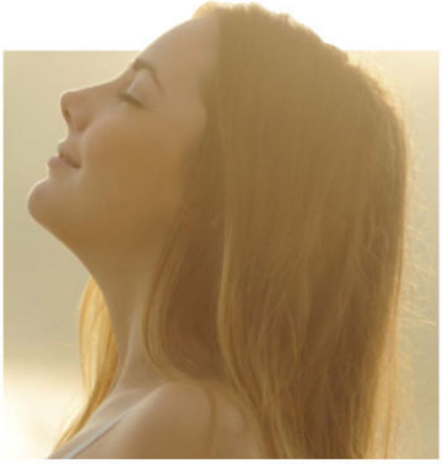
Monozygotic (MZ), or identical, twins are formed by the egg splitting soon after fertilisation, and from those identical split groups of cells, two separate foetuses will start to grow. Monozygotic twins are therefore genetically identical and will be the same sex, except when mutations or very rare syndromes occur during gestation. No reason is known for the occurrence of the split of the ovum, and the father has no influence over whether identical twins are produced.

Dizygotic (DZ) twins, however, are produced when the female's ovaries release two ovum and both are fertilised and implanted in the womb wall. They can be known as fraternal twins as genetically they are likely to only be as similar as siblings. They will also have separate placentas, where MZ twins will share one, as they are entirely separate to each other – they are just sharing the womb during gestation. This kind of twin is far more common.





How do alveoli help you breathe?



The lungs are filled with tiny balloon-like sacs that keep you alive

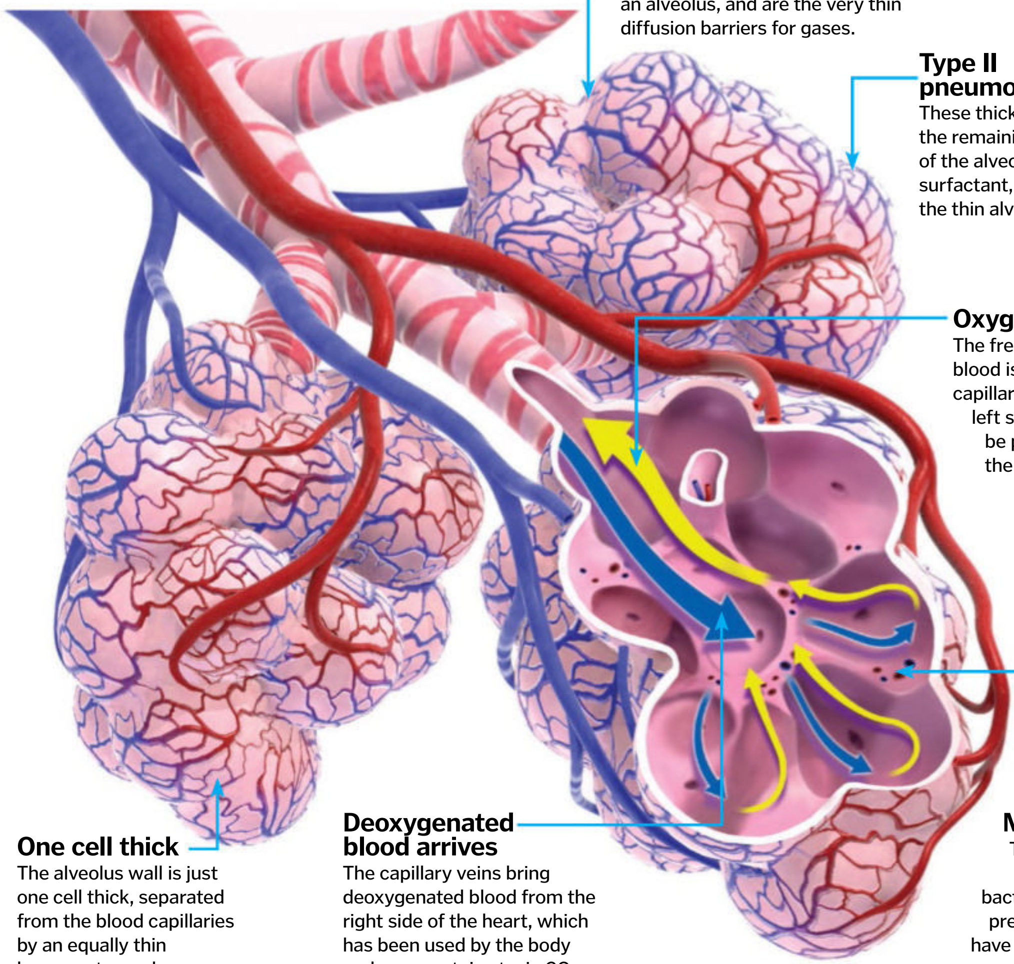
Gas exchange occurs in the lungs, where toxic gases (carbon dioxide) are exchanged for fresh air with its unused oxygen content. Of all the processes in the body that keep us functioning and alive, this is the most important. Without it, we would quickly become unconscious through accumulation of carbon dioxide within the bloodstream, which would poison the brain.

The two lungs (left and right) are made up of several lobes, and the fundamental building blocks of each are the tiny alveolus. They are the final point of the respiratory tract, as the bronchi break down into smaller and smaller tubes, leading to the alveoli, which are grouped together and look like microscopic bunches of grapes. Around the alveoli is the epithelial layer – which is amazingly only a single cell thick – and this is surrounded by extremely small blood vessels called capillaries. It is here that vital gas exchange takes place between the fresh air in the lungs and the deoxygenated blood within the capillary venous system on the other side of the epithelial layer.

The alveoli of the lungs have evolved to become specialised structures, maximising their efficiency. Their walls are extremely thin and yet very sturdy. Pulmonary surfactant is a thin liquid layer made from lipids and proteins that coats of all the alveoli, reduces their surface tension and prevents them crumpling when we breathe out. Without them, the lungs would collapse.

Alveoli anatomy

How alveoli enable gas exchange



Type I pneumocytes
These large, flattened cells form 95 per cent of the surface area of an alveolus, and are the very thin diffusion barriers for gases.

Type II pneumocytes
These thicker cells form the remaining surface area of the alveoli. They secrete surfactant, which prevents the thin alveoli collapsing.

Oxygenated blood
The freshly oxygenated blood is taken away by capillaries and enters the left side of the heart, to be pumped through the body.

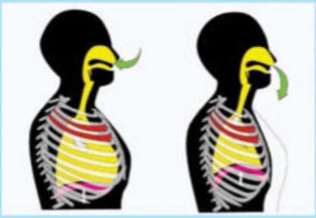
One cell thick
The alveolus wall is just one cell thick, separated from the blood capillaries by an equally thin basement membrane.

Deoxygenated blood arrives
The capillary veins bring deoxygenated blood from the right side of the heart, which has been used by the body and now contains toxic CO_2.

Macrophages
These are defence cells that digest bacteria and particles present in air, or that have escaped from the blood capillaries.

Breathe in, breathe out

The alveoli function to allow gas exchange, but since they're so small, they can't move new air inside and out from the body without help. That's what your respiratory muscles and ribs do, hence why your chest moves as you breathe. The diaphragm, which sits below your heart and lungs but above your abdominal organs, is the main muscle of respiration. When it contracts, the normally dome-shaped diaphragm flattens and the space within the chest cavity expands. This reduces the pressure compared to the outside atmosphere, so air rushes in. When the diaphragm relaxes, it returns to its dome shape, the pressure within the chest increases and the old air – now full of expired carbon dioxide – is forced out again. The muscles between the ribs (called intercostal muscles) are used when forceful respiration is required, such as during exercise Try taking a deep breath and observe how both your chest expands to reduce the pressure!



How do dilating eye drops work?

Discover how they are used to diagnose and treat eye conditions

Our eyes need good care to stay healthy

Sight is one our most important senses, so maintaining good eye health is absolutely essential. However, eyesight problems can be difficult to detect or treat on the surface, so specialist eye doctors will often use dilating eye drops in order to get a better look inside the eye at the lens, retina and optic nerve.

The drops contain the active ingredient atropine, which works by temporarily relaxing the muscle that constricts the pupil, enabling it to remain enlarged for a longer period of time so a thorough examination can be performed. Some dilating eye drops also relax the muscle that focuses the lens inside the eye, which allows an eye doctor or optometrist to measure a prescription for young children who can't perform traditional reading tests.

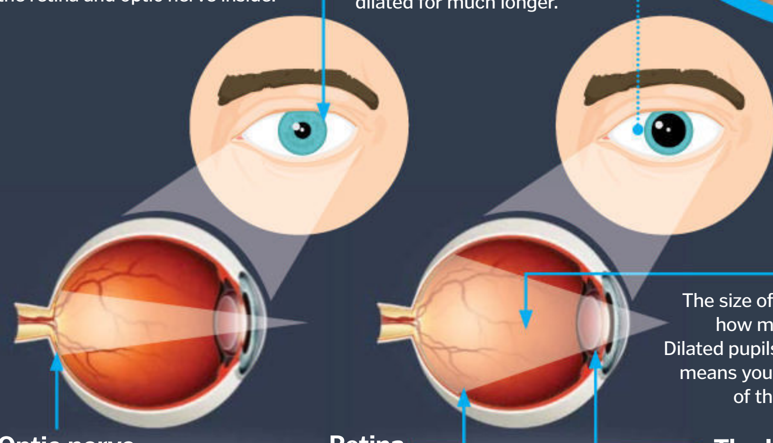
Dilating eye drops are not only used to help perform procedures, they may also be administered after treatment, as they can prevent scar tissue from forming. They are also occasionally prescribed to children with lazy-eye conditions, as they will temporarily blur vision in the strong eye, causing the brain to use and strengthen the weaker eye.

Before and after

A better look inside the eye

Contracted pupil
A contracted pupil will appear much smaller and let less light into the eye, which makes it difficult to see the retina and optic nerve inside.

Dilated pupil
Dilating eye drops will temporarily paralyse the muscle that constricts the pupil, which means the pupil will remain dilated for much longer.



Ray of light
The size of the pupil will determine how much light enters the eye. Dilated pupils let in more light, which means you can see a larger portion of the retina and optic nerve.

Optic nerve
The optic nerve carries electrical impulses from the retina to the brain, which then interprets them as visual images.

Retina
This light-sensitive tissue converts incoming light into electrical impulses. These impulses are then sent to the optic nerve.

The lens
It is positioned behind the pupil and helps focus light onto the retina. Some dilating eye drops relax the muscle around it to prevent the lens from focusing.

Why do we get migraines?

Discover how these mega-headaches strike

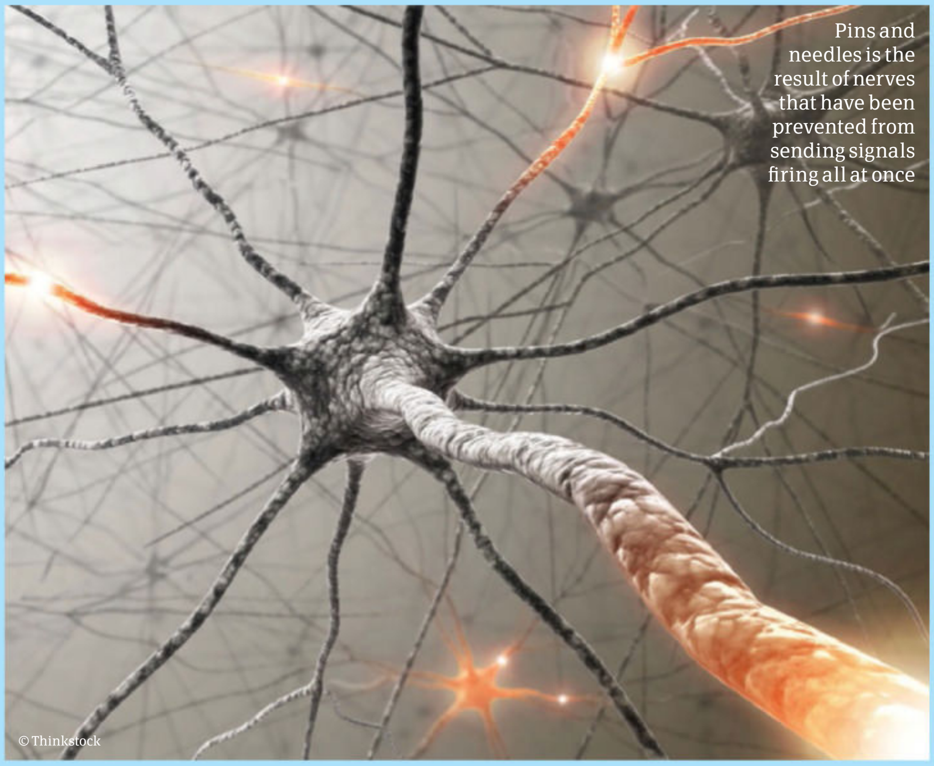
Those who suffer from migraines know they are a constant concern as they are liable to strike at any time. Essentially, a migraine is an intense pain at the front or on one side of the head. This usually takes the form of a heavy throbbing sensation and can last as little as an hour or two and up to a few days. Other symptoms of a migraine include increased sensitivity to light, sound and smell, so isolation in a dark and quiet room often brings relief. Nausea and vomiting is also often reported, with pain sometimes subsiding after the sufferer has been sick.

It is thought that migraines occur when levels of serotonin in the brain drop rapidly. This causes blood vessels in the cortex to narrow, which is caused by the brain spasming. The blood vessels widen again in response, causing the intense headache. Emotional upheaval is often cited as a cause for the drop in serotonin in the brain, as is a diet in which blood-sugar levels rise and fall dramatically.

What are 'pins and needles'?

The numb sensation of your leg 'going to sleep' isn't caused by cutting off the blood circulation. It's the pressure on the nerves that is responsible. This squeezes the insulating sheath around the nerve and 'shorts it out', blocking nerve transmission. When pressure is released, the nerves downstream from the pinch point suddenly all begin firing at once. This jumble of unco-ordinated signals is a mixture of pain and touch, hot and cold all mixed together, which is why it's excruciating.

"This squeezes the insulating sheath around the nerve and 'shorts it out'"



Pins and needles is the result of nerves that have been prevented from sending signals firing all at once

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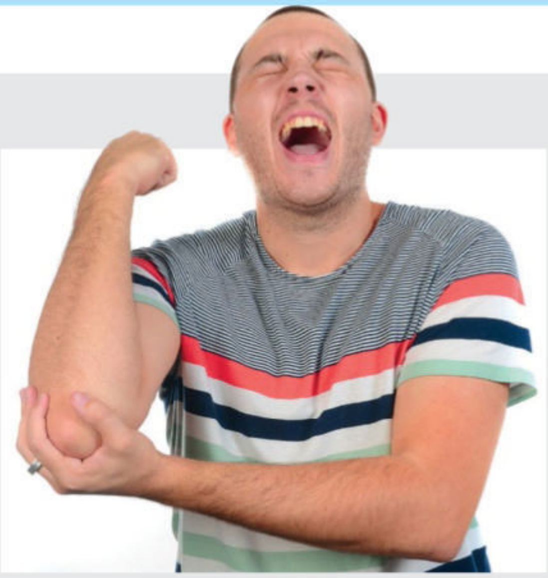
Why do paper cuts hurt so much?

Paper can cut your skin as it is incredibly thin and, if you were to look at it under a high-powered microscope, it has serrated edges. Critically though, a sheet of loose paper is far too soft and flexible to exert enough pressure to pierce the skin, hence why they are not a more frequent occurrence. However, if the paper is fixed in place – maybe by being sandwiched within a pack of paper – a sheet can become stiff enough to attain skin-cutting pressure. Paper cuts are so painful once inflicted as they stimulate a large number of pain receptors – nociceptors send nerve signals to the spinal cord and brain – in a very small area due to the razor-type incision. Because paper cuts tend not to be deep, bleeding is limited, leaving pain receptors open to the environment.



Are there other 'funny bones' in the body?

The term 'funny bone' is misleading because it refers to the painful sensation you experience when you trap your ulnar nerve between the skin and the bones of the elbow joint. This happens in the so-called cubital tunnel, which directs the nerve over the elbow but has little padding to protect against external impacts. The ulnar nerve takes its name from the ulna bone, which is one of two bones that runs from the wrist to the elbow; the other is the radial bone, or radius.

No other joint in the human skeleton combines these conditions and duplicates the this erroneously named reaction so we only have one 'funny bone'.

Why do our muscles ache?

Learn what causes stiffness and pain in our muscles for days after exercise

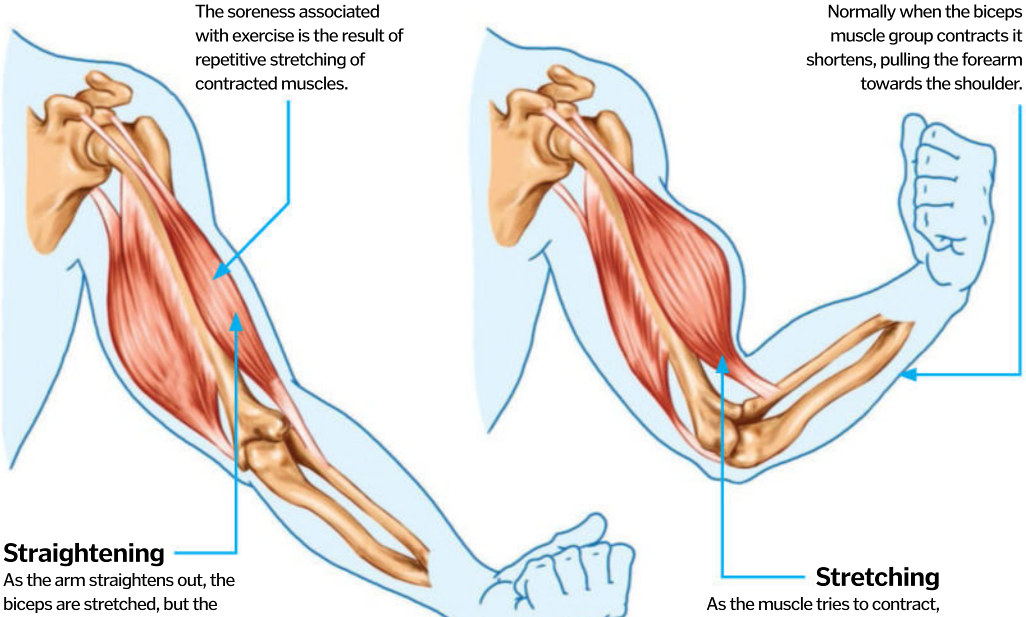
Normally, when our muscles contract they shorten and bulge, much like a bodybuilder's biceps. However, if the muscle happens to be stretched as it contracts it can cause microscopic damage.

The quadriceps muscle group located on the front of the thigh is involved in extending the knee joint, and usually contracts and shortens to straighten the leg. However, when walking down a steep slope, say, the quadriceps contract to support your body weight as you step forward, but as the knee bends, the muscles are pulled in the opposite direction. This tension results in tiny tears in the muscle and this is the reason that downhill running causes so much delayed-onset pain.

At the microscopic level, a muscle is made up of billions of stacked sarcomeres, containing molecular ratchets that pull against one another to generate mechanical force. If the muscle is taut as it tries to contract, the sarcomeres get pulled out of line, causing microscopic damage. The muscle becomes inflamed and fills with fluid, causing stiffness and activating pain receptors – hence that achy feeling you get after unfamiliar exercise.

Weight lifting and the body

What happens to your biceps when you pump iron?

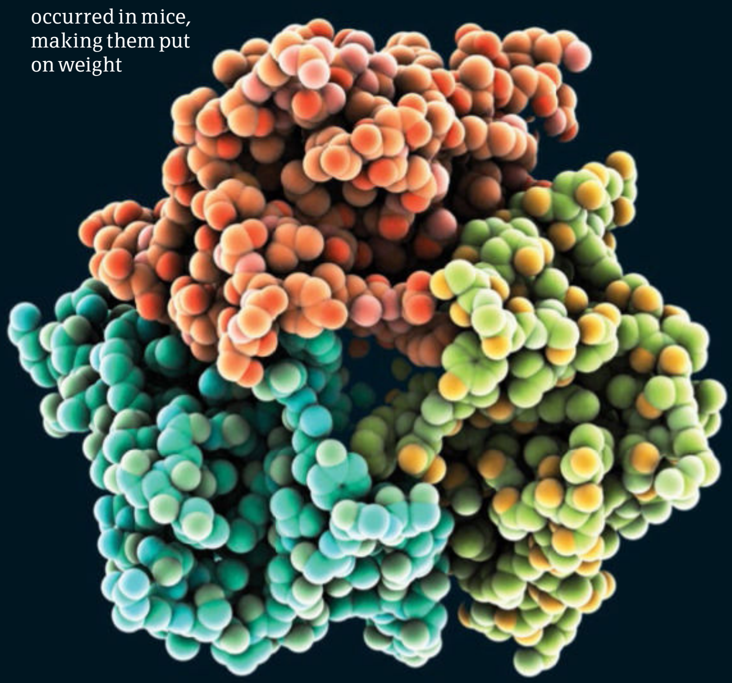


Pain
The soreness associated with exercise is the result of repetitive stretching of contracted muscles.

Bending
Normally when the biceps muscle group contracts it shortens, pulling the forearm towards the shoulder.

Straightening
As the arm straightens out, the biceps are stretched, but the weight is still pulling down on the hand, so the muscles remain partly contracted to support it.

Stretching
As the muscle tries to contract, the weight pulls in the opposite direction, causing microscopic tears within the muscle cells.



The leptin (LEP) gene was originally discovered when a random mutation occurred in mice, making them put on weight

The fat hormone

Discover how the body manages to keep track of its energy reserves

In order to know how much food to eat, the human body needs a way of assessing how much energy it currently has in storage. Leptin – more commonly known as the 'fat hormone' – essentially acts as our internal fuel gauge. It is made by fat cells and tells the brain how much fat the body contains, and whether the supplies are increasing or being used up.

Food intake is regulated by a small region of the brain called the hypothalamus. When fat stores run low and leptin levels drop, the hypothalamus stimulates appetite in an attempt to increase food intake and regain lost energy. When leptin levels are high, appetite is suppressed, reducing food intake and encouraging the body to burn up fuel.

It was originally thought that leptin could be used as a treatment for obesity. However, although it is an important regulator of food intake, our appetite is affected by many other factors, from how full the stomach is to an individual's emotional state or their food preferences. For this reason, it's possible to override the leptin message and gain weight even when fat stores are sufficient.

Why do the upper arm and upper leg have only one bone?

The makeup of the human skeleton is a fantastic display of evolution that has left us with the ability to perform incredibly complex tasks without even thinking about them. There are several different types of joint between bones in your body, which reflect their function; some are strong and allow little movement, others are weak but allow free movement. The forearm and lower leg have two bones, which form plane joints at the wrist and ankle. This type of joint allows for a range of fine movements, including gliding and rotation. The hinge joints at your elbows and knees allow for less lateral movement, but they are strong. Shoulders and hips, though, are ball-and-socket joints, which allow for a wide range of motion.

"Laughter is produced by the same coughing"

Why shouldn't we eat raw meat?

Meat can harbour many different bacteria, viruses and even parasites. Cooking meat properly destroys them, making meat much safer for consumption. Bacteria and viruses can make you ill, while parasites can grow inside your gut and even migrate to your brain. Food poisoning is a very serious business and by not cooking meat thoroughly, you are greatly increasing your chances of getting something nasty. People quite often eat raw meat such as steak tartare, but it requires extra care in the preparation. Besides safety, cooking meat also makes it taste better. By cooking meat and other foods, humans can get much more energy than from chewing raw food alone.

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How do inoculations work?

The terms 'inoculation' and 'vaccination' are used interchangeably. They involve introducing a foreign substance (antigens) into the body, causing antibody production. These can either be dead, made less harmful, or just contain certain bits that cause disease.

White blood cells called B lymphocytes recognise these antigens, and produce antibodies to neutralise them. After the initial encounter, a group of B lymphocytes are made called 'memory cells', which produce antibodies faster if exposed to the same antigen again.

"They involve introducing antigens into the body"

© Mark Wolfe

What causes insomnia?

Why checking your phone before bed could be spoiling your sleep

Most of us experience insomnia at some point in our lives, finding it difficult to drift off and stay asleep, despite having plenty of opportunity to. Typical causes of insomnia include stress and anxiety, but did you know that your gadgets could be to blame, too?

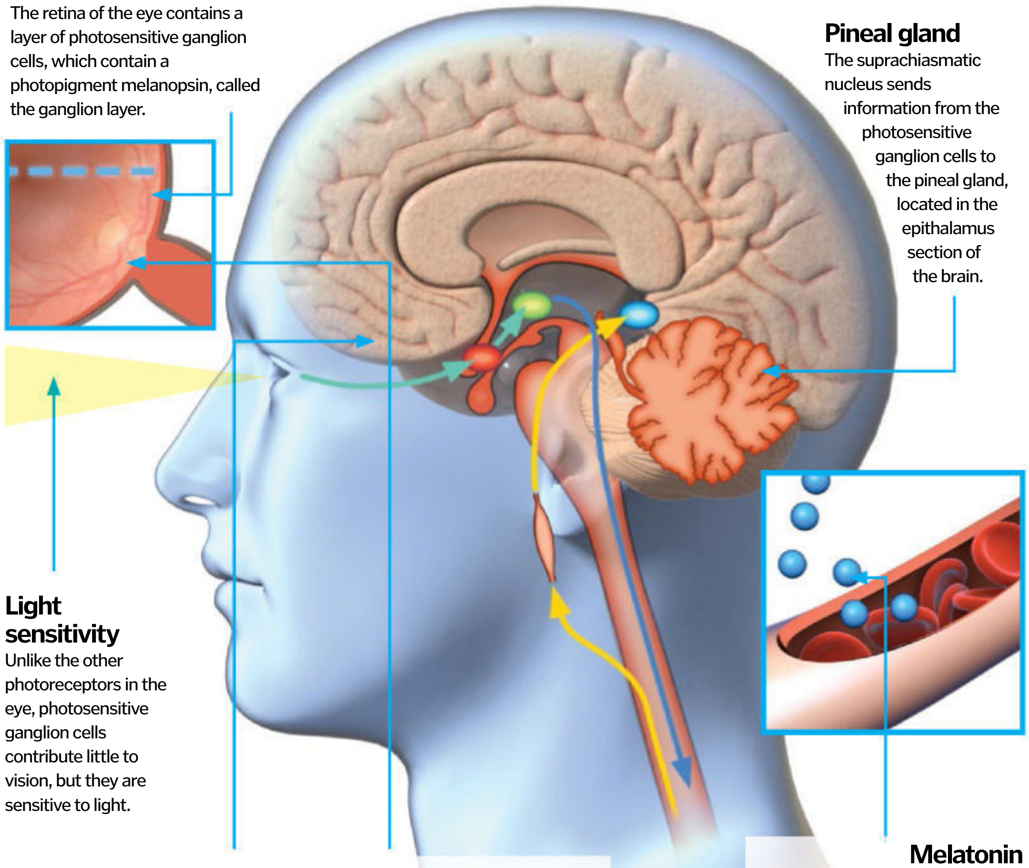
Our sleepiness and wakefulness throughout the day and night is regulated by our circadian rhythm. This is essentially our body clock, creating physical, mental and behavioural changes that occur in our bodies over a roughly 24-hour cycle. Circadian rhythms are found in most living things, including animals, plants and many tiny microbes, and they are created by natural factors in the body. However, they also respond to signals from the environment, such as light, so that we remain in sync with the Earth's rotation.

All forms of light, both natural and artificial, affect our body clock, as when the photosensitive retinal ganglion cells in our eyes detect light, they send this information to the suprachiasmatic nucleus (SCN) – the group of nerves in the brain that control circadian rhythms. When light is detected, the SCN will delay the production of melatonin, a hormone that sends us to sleep. However, the retinal ganglion cells have been found to be particularly sensitive to the blue light with a short wavelength of 480 nanometres emitted by most computer, smartphone and tablet screens. Exposure to a lot of this type of light in the hours before we go to bed has been proven to suppress melatonin levels, making it difficult for us to get to sleep.

"Laughter is produced by the same coughing"

Light sensitivity

How light affects your ability to sleep



The ganglion layer
The retina of the eye contains a layer of photosensitive ganglion cells, which contain a photopigment melanopsin, called the ganglion layer.

Pineal gland
The suprachiasmatic nucleus sends information from the photosensitive ganglion cells to the pineal gland, located in the epithalamus section of the brain.

Light sensitivity
Unlike the other photoreceptors in the eye, photosensitive ganglion cells contribute little to vision, but they are sensitive to light.

Suprachiasmatic nucleus
The suprachiasmatic nucleus is a tiny area of neurons, located in the hypothalamus area of the brain, which controls circadian rhythms.

Optic nerve
The photosensitive ganglion cells have long fibres that connect to the optic nerve and eventually reach the suprachiasmatic nucleus.

Melatonin
When the photosensitive ganglion cells detect darkness, a message is sent to the pineal gland to produce melatonin, a hormone that can cause drowsiness.

Blocking blue light

The best way to reduce your exposure to blue light is to avoid staring at a screen within two hours prior to going to bed. Instead, illuminate the room with the warmer, longer-wavelength light from regular incandescent bulbs or even candles. However, if you just can't resist staring at your computer or phone before bed, there are ways that you can do so and still get a good night's sleep. Wearing special glasses with amber-coloured lenses will filter out blue, low-wavelength light, allowing you to stare at your screen for as long as you like. Companies such as Uvex (**uvex-safety.co.uk**) make blue-blocking glasses and goggles in a range of styles. Alternatively, you could use computer software such as f.lux (**justgetflux.com**) and smartphone apps such as Twilight (**play.google.com**) that automatically adjusts your screen to filter out blue light between sunset and sunrise, replacing it with a softer red light.

Filter out blue light with a pair of amber-tinted glasses

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How quickly does human hair grow?

Human hair grows on average 1.25 centimetres (0.5 inches) per month, which is equivalent to about 15 centimetres (six inches) per year. There are several variables that can affect hair's growth rate such as age, health and genetics. Each hair grows in three stages, the first being the anagen phase where most growth occurs. The longer your hair remains in this stage dictates how long and quickly it develops; this can last between two and eight years and is followed by the catagen (transitional) and telogen (resting) phases. Hair growth rates vary across different areas of the head, with that on the crown growing the fastest.

"Each hair grows in three stages, the first being the anagen phase"

Why does blonde hair look darker when it's wet?

Dry blonde hair has a rough, tiled surface – something like fish scales. When light rays hit these scales, they bounce off in all directions. Some of the light reaches your eyes and makes the hair look brighter; it's like shining a torch on the hair.

When you wash your hair, a thin film of water forms around each fibre. Light rays pass into the film of water, bounce around inside, and there's a chance they'll get absorbed by the hair. Since the light gets trapped inside the water, less of it reaches your eyes, so the hair actually appears a lot darker.

"A thin film of water forms around each fibre"

Why do we get angry?

How does this primal emotion override our normal thought processes?

As far as we know, anger is one of the oldest and most primitive forms of emotion. It is believed to have been hard-wired in our brains many thousands of years ago, to help us survive tougher times. Back then, resources like food, potential mates and shelter were relatively scarce. Anger was therefore a vital emotion, giving our ancestors the necessary drive and power to survive when their safety, or chance to mate, was threatened.

Although our lives are less frequently in danger than our ancestors', our brains still react to certain anger triggers, one of which is being treated unfairly. As soon as someone shouts at you or gives you an angry look, the amygdala in your brain sounds the alarm, prompting the release of two key hormones – adrenaline and testosterone – which prime the body for physical aggression.

As well as the amygdala, the prefrontal cortex is also activated by the anger trigger. This part of the brain is responsible for decision-making and reasoning, making sure you don't react irrationally to the situation. According to studies, the time between initially getting angry and the more measured response from the prefrontal cortex is less than two seconds. This would explain the popularity of the age-old advice of counting to ten if you feel your blood boiling.

It's widely accepted that men and women feel anger differently. Women are more likely to feel anger slowly build up, which takes time to diffuse, whereas men are more likely to describe the feeling as a fire raging within them that quickly eases. This is thought to be due to men having a larger amygdala than women, and is why a man is statistically more likely to be aggressive than a woman.

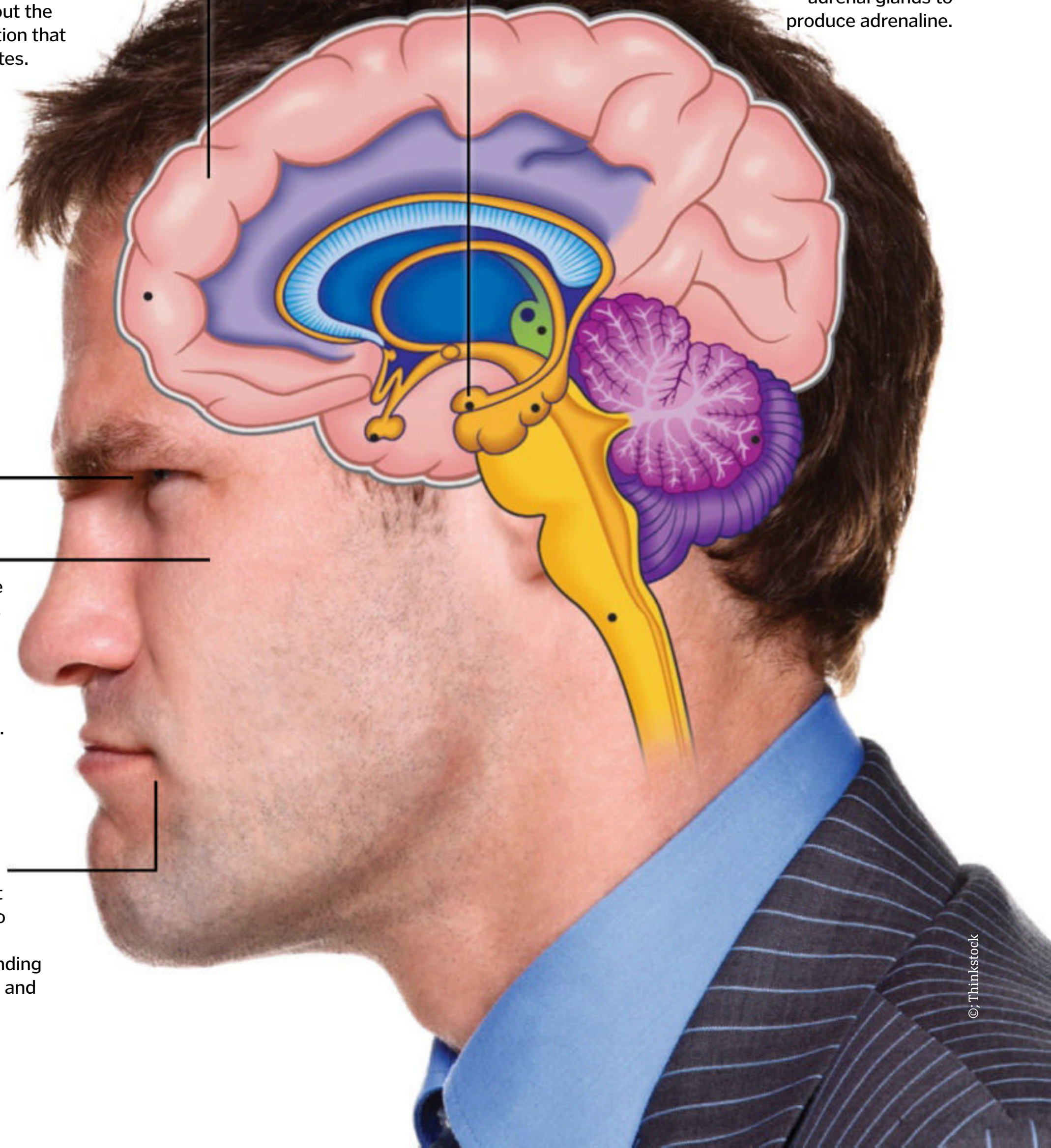
Can getting angry be good for you?

Many people view anger as a negative emotion that wastes energy and has no benefits. Yet as with all human emotions, anger has evolved to serve an evolutionary purpose. Having said this, getting angry will only have a positive effect if it is used in the correct way. If we sit down and discuss why someone or something has made us angry, then anger is working in the right way; if we can't regulate our anger response, it's unlikely to improve a situation in the long run. Studies have shown that releasing anger in a rational way is actually good for you. On the other hand, storing anger up is known to negatively affect certain people, potentially leading to depression. Constant, chronic anger can lead to high blood pressure and even heart disease in the long term.

Explaining why something has made you angry is much more likely to resolve an issue than exploding with rage

Inside your brain

Find out how the brain processes anger and what happens to your body as a result



Prefrontal cortex
The decision-making area of the brain is also activated, and acts to balance out the potentially rash reaction that the amygdala promotes.

Amygdala
The amygdala alerts your body, preparing it for potential action. It sends signals telling your adrenal glands to produce adrenaline.

Trigger
Seeing or hearing a trigger event can spark an anger response from the amygdala in just a quarter of a second.

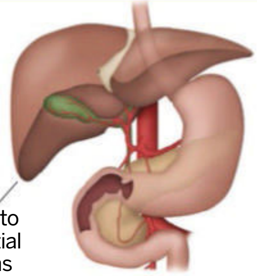
Flushing red
The rise in adrenaline causes blood vessels to dilate to improve blood flow. The dilation of the veins in your face can make your face flush.

Teeth grinding
People have different physical responses to anger, but common reactions include grinding teeth, clenching fists and tensing muscles.

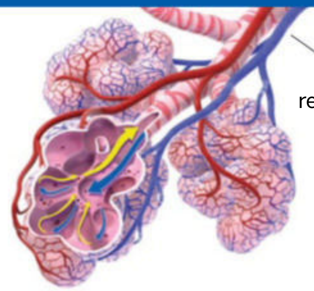
HUMAN ANATOMY THE BODY AT WORK CURIOUS QUESTIONS

HOW IT WORKS BOOK OF THE HUMAN BODY

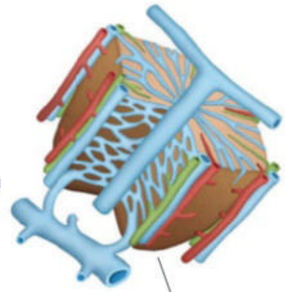
How are hormones produced?



Guide to essential organs



Human respiration



Explore liver structure

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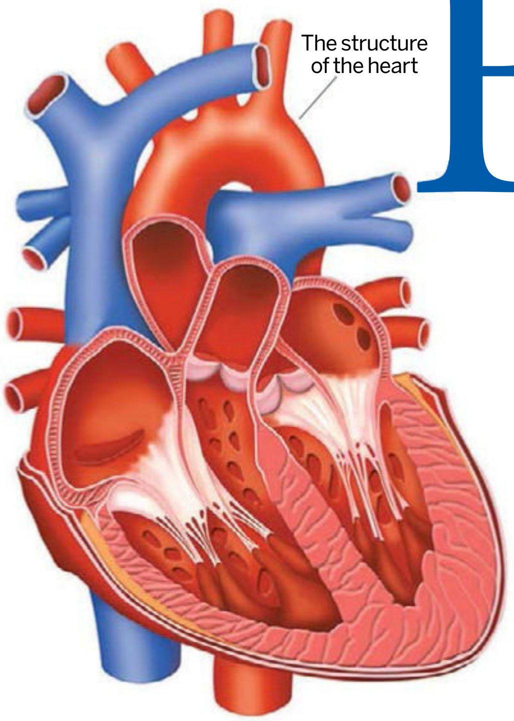
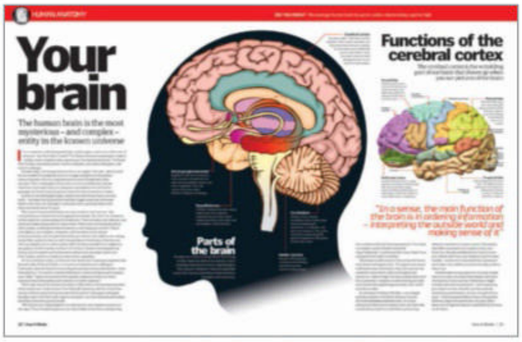


The structure of the heart



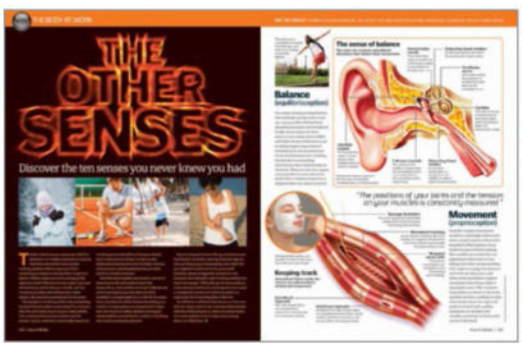
Human anatomy

Get to know the essentials of the human body, from the structure of each cell to the functions of the large intestine

How taste works

What makes the nose run?

The lining of vessel walls

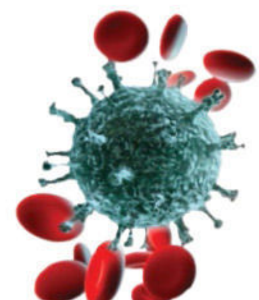


The body at work

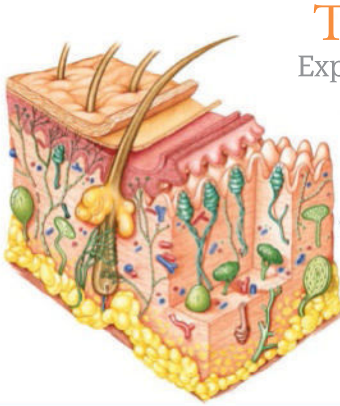
Explore the intimate details behind complex systems, processes and behaviours

Curious questions

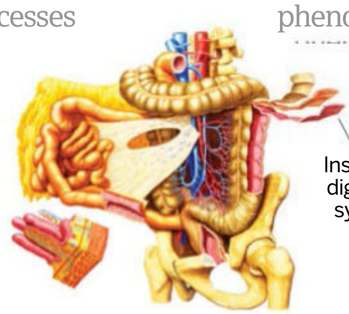
Understand the weird and wonderful phenomena of the human body, from bruises to hiccups



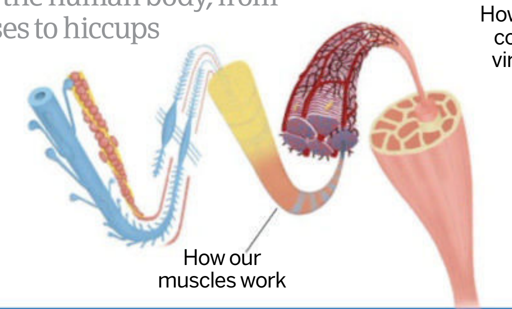
How do we combat viruses?



Take a look under the skin



Inside the digestive system



How our muscles work

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